GEOLOGICAL SURVEY OF THE UNITED KINGDOM

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MEMOIRS OF THE GEOLOGICAL SURVEY.
ENGLAND AND WALES.

THE GEOLOGY
OF THE
NORTH STAFFORDSHIRE COALFIELDS.

BY

WALCOT GIBSON, B.Sc., F.G.S.

With Contributions by

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And a Palæontological Account, with List of Fossils,

By JOHN WARD, F.G.S.

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PREFACE.

The following Memoir contains a description of the chief coal-fields of North Staffordshire.

The original Geological Survey was made on the Old Series one-inch maps, Sheets 72 N.W., 73 N.E. and 81 S.W., published during the years 1852-1864, the Coal-measures having been mapped by Sir W. W. Smyth, the Permian and Trias by Prof. E. Hull, and the subdivisions of the "Yoredale Rocks" and Millstone Grit by Prof. A. H. Green. The Memoir on the Iron Ores of North Staffordshire by Sir W. W. Smyth, published in 1862, contains a summary of the geological features of the coalfields; and brief accounts of the northern end of the Pottery Coalfield, known as the Biddulph Trough, were published in 1866, in the Memoir on the Geology of Stockport, Macclesfield, Congleton, and Leek, by Prof. Hull and Prof. Green.

The re-survey on the six-inch scale was commenced in 1898 and completed in 1901. The Pottery Coalfield was surveyed by Messrs W. Gibson and C. B. Wedd, and the Cheadle Coalfield by Mr. George Barrow. The area is included in the New Series, one inch Sheets 110, 123, 124. Drift and Solid Editions of Sheet 123, with an explanatory memoir, were published in 1902. A description of the Cheadle Coalfield, with an accompanying geological map (part of Sheet 124), was published in 1903. A Sheet of Vertical Sections giving sections of shafts in the Pottery Coalfield was published in 1901. Sheet 110, which includes a small portion of the Pottery Coalfield, has been prepared for publication; while thirty-five quarter sheets on the six inch scale, including the whole of the ground described in this Memoir were published with geological lines in 1904.

The present volume, which contains the detailed descriptions furnished by each geologist, of the area surveyed by himself, has been largely written and edited by Mr. Gibson, who personally carried out the greater part of the field-work. In the Palæontological portion the Survey fortunately obtained the services of Mr. John Ward of Longton, whose knowledge of the district extends over nearly 50 years. In 1862 he supplied lists of fossils to the Survey Memoir on the Iron Ores of North Staffordshire; and he has now generously contributed copious lists of fossils, together with a palæontological statement in reference to them, the results of his long continued researches in the North Staffordshire coalfields. In this work Mr. Ward, and through him the Geological Survey, are indebted to several geologists—to Dr. Traquair and Dr. A. Smith Woodward for naming the Fossil Fishes; to Mr. R. Kidston for naming the plants; and to Dr. Wheelton Hind not only for naming the Lamellibranchs, but for much time spent in the preparation of

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the fossil lists and also for kindly help and information rendered during the progress of the re-survey. To Mr. J. T. Stobbs we are indebted for much information, more especially in connexion with the marine bands in the Coal-measures, which owing mainly to his researches are proving to be a most reliable guide to the miner for fixing the position of the seams of coal. The Survey has also to acknowledge its great indebtedness to Colliery Proprietors, Mine Managers and Mining Engineers, who have given much valuable information.

In the account of the Carboniferous rocks it has been found advisable to adopt purely descriptive terms for the various sub-divisions. Though, as is well known, the vertical distribution of both plants and fishes points to a two-fold division of the Carboniferous rocks, the exact position and nature of the boundary line has not yet been determined for North Staffordshire. For the old term "Yoredale Beds" the term Pendleside Series, introduced by Dr. Wheelton Hind and Mr. J. Allen Howe, seems preferable, since it only implies a correlation with similar beds occupying the same stratigraphical position on Pendle Hill in Lancashire.

For similar reasons the terms Upper, Middle and Lower Coal-measures have not been adopted; since the positions of the palæontological boundary lines or zones, which may give a definite significance to the terms, have not been determined with accuracy.

It is evident, as pointed out by Jukes long ago, that as regards the higher portions of the Coal-measures, North Staffordshire presents the type development for the Midlands.* In that region Mr. Gibson has established a definite stratigraphical sequence in the comparatively barren strata which conformably overlie the productive Coal-measures, and he has also proved that the same sequence may be recognised in the other coalfields of the Midland area.

The points of special economic interest are given in a separate chapter, considerable attention being paid to the future development of the coalfield.

The portion of the memoir descriptive of the Cheadle Coalfield is largely a reprint from the separately published memoir on this small coalfield by Mr. G. Barrow. Since the publication of that memoir, the prediction there confidently made that the Dilhorne Coal underlay the Delphouse area has been verified by actual sinking.

Geological Survey Office,
Jermyn Street, London.
6th January, 1905.

J. J. H. TEALL,
Director.

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* Letters and Extracts from the Addresses and occasional Writings of J. Beete Jukes, edited by his sister, p. 346.

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PART I.

THE POTTERY COALFIELD.

BY

W. GIBSON AND C. B. WEDD.

CHAPTER I.

INTRODUCTION.

AREA DESCRIBED—HISTORICAL OUTLINE—FORM OF GROUND AND ITS RELATION TO GEOLOGICAL STRUCTURE—RIVER SYSTEMS AND STREAMS—ALTERATION OF DRAINAGE.

Area Described.—The present memoir mainly treats of the Coal-measures constituting the detached basins of the Potteries, Shaffalong and Cheadle Coalfields situated in North Staffordshire, at the south-western termination of the Pennine Chain, where this commences to sink gradually on the south beneath the Midland Triassic Plain, or where it abruptly descends on the west towards that of Cheshire. As the Pottery and Cheadle Coalfields form distinct units in themselves, and were separately surveyed, they can be conveniently described apart; and of these the vastly more important Pottery Coalfield claims our first attention.

In the shape of a triangle, of which the surface area slightly exceeds 100 square miles,* the Coal-measures of the Pottery Coalfield extend from Alders Farm, two miles east of Congleton, at the apex of the triangle, to a base line joining Moddershall and Madeley on the south. The coalfield is included in Sheets 110 and 123; in addition two narrow tongues proceed from the eastern and western corners of the triangle into the heart of the Trias country, situated in Sheet 139, of which only the areas occupied by Coal-measures have been re-surveyed.

The Pottery Coalfield deserves the closest attention of all students of the great and important Carboniferous System, for not only is it exceptionally rich in coal and ironstone, but the completeness of the sequence of the strata, and the number, variety, and preservation of its organic contents, stand unrivalled in the Midlands. Moreover, the local sequence of Coal-measures has been found to form the type to which that of the other Midland coalfields may conveniently be referred. This is due to the central situation within the wide basin of older rocks, in which the material constituting the Coal-measures

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* Includes area occupied by the red measures formerly considered to be of Permian age.

accumulated; while, in addition, the relationship of the Trias, and the effects of the great earth movements preceding this later geological epoch, can here be studied to an extent impossible in the neighbouring coalfields.

Historical Outline.—Towards the middle of the 17th century coal and ironstone mining appears to have been actively carried on in the district, for writing in 1686, Dr. Plot mentions the winning of coal by means of "foote railles,"* he draws attention to the varied inclination of the seams, their outcrop and properties, as well as the different classes of ironstones then dug; though it is evident from his descriptions that the workings were extremely shallow. The first complete account of the geology of the area is that of Dr. Garner whose observations on The Natural History of the County of Stafford† reveal true geological insight; and who, as one of the founders of the North Staffordshire Naturlists' Field Club, in 1866, did so much to encourage a local interest in geology. The important character of the coalfield, more especially the valuable nature of the ironstones, was fully recognised by Sir W. W. Smyth,‡ who seemed surprised at the small development the iron industry had reached in the early sixties. Professor Hull, who geologically surveyed the major portion of this part of England, refers more than once to the possibilities presented by the mineral wealth of the district.§ No one, however, has added so much to our knowledge as Mr. John Ward, whose life-long devotion to the science will be gathered from his account of the organic remains accompanying this memoir. Mr. Ward has directed his attention chiefly to the Fishes, but, since 1892, the neglected study of the Carboniferous Lamellibranchiata has received the attention of Dr Wheelton Hind, who has also closely investigated the fauna of the Carboniferous rocks older than the Coal-measures. The re-survey on the six-inch scale has added to the knowledge of the sequence of the rocks and their arrangement; while the recent work of Mr. J. T. Stobbs has revealed the truly marine character of much of the Coal-measures to a far greater extent than was hitherto suspected.

The want of appreciation of the exceptional wealth in coal and ironstone, has, no doubt, chiefly resulted from North Staffordshire having, in course of time, become the centre of the pottery industry in this country. This trade may be said to have commenced its celebrated career with the discovery of Ehlers in 1690; but was established, and received its great impetus from the genius of Sir Josiah Wedgewood towards the middle of the 18th Century. That the manufacture of

* The Natural History of Staffordshire by Robert Plot, 1686. p. 130.

† Dr. R. Garner. The Natural History of the County of Stafford, 1844.

‡ Iron ores of Great Britain, part iv., *Mem. Geol. Survey*, 1861.

§ The Permian and Triassic Rocks of the Midland Counties (1869). Evidence before the Coal Commission (1871). The Coalfields of Great Britain (4 Ed., 1881).

pottery has for long constituted the staple industry of the district is shown by the location of the chief towns; which are not situated along the outcrops of the main seams of coal, but which extend in an almost continuous line along the outcrop of the quick-burning coals, clays and marls once used in the manufacture of coarse pottery, and still needed for the construction of vessels in which the pottery is now placed in the kilns.

Form of the Ground and its relation to Geological Structure.—The topographical features of the area are at once seen to have resulted from the saddle and trough arrangement of the groups of strata, coupled with the ordinary processes of denudation, which have worn away the softer rocks, leaving the harder materials standing out as ridges. Thus the hollow, 360 feet above Ordnance Datum, at Stoke-upon-Trent, extending along the eastern side of the coalfield, coincides in position with a well-marked trough or syncline; and is, at the same time, occupied by the softer strata of the Coal-measures. The ground swiftly rises on the flanks of a saddle or anticline bounding the coalfield on the east and bringing the alternating hard and soft beds of the Millstone Grit to the surface. The grits give rise to long ridges, known as "Edges," of which Brown Edge (888 feet. O. D.) and Badderley Edge (787 O. D.) may be cited as conspicuous examples, while the alternating shales have been carved by denudation into long, narrow, and frequently deep valleys. Westward of the main hollow of the Pottery Coalfield the ground again rapidly rises, and once more this elevation coincides with the saddle arrangement of the rocks known locally as the "Staffordshire Anticline," which attains an elevation of 744 feet O. D. at Alsager Bank. North of this point the anticline consists of several sections, each of which stands out at the surface as a ridge. The prominent features in the central, southern and western parts of the coalfield are, therefore, mainly of structural origin. Denudation, on the other hand, plays a much less important role. To this agency we may attribute the ridges which diversify the central depression, and being composed of sandstone, have better resisted weathering action. The greater height of the anticline at Alsager Bank may also in part be due to the capping of sandstone forming the crest of the dome.

Evident as this connexion of physical aspect and geological structure is in most of the tracts of Carboniferous rocks, it is probably nowhere more pronounced than around the northern part of the Pottery Coalfield; where the rugged edges of the Millstone Grit as they curve round the valley of the Biddulph syncline, the long broad anticlinal ridge of Lask Edge, the shallow upraised basins east and west of the Rudyard Valley also rimmed with massive grits, have arrested the attention of previous observers. Two main factors combine to accentuate the relationship of structure to scenery. Firstly, the arrangement in groups of alternations of hard and soft beds, each group roughly distinctive

in lithological character, and capable of offering different degrees of resistance to the forces of denudation—secondly, a simple and clearly defined system of folding which has subjected these groups, each in turn, to the maximum or minimum influence of these forces. Both are agents in the production of a landscape sharply contrasted with the Drift-plain on the west, and the gentle slope of the Triassic rocks which pass under it. Perhaps in one instance only is the inter-relationship of fold and feature less apparent. In the southern end of Mow Cop, the grit-ridge is clearly anticlinal; but northward from here, lower and softer strata reach the surface along the axis of the fold. The high grit-feature of the eastern limb diverges to the north-east, while faults, by depressing the western limb of the fold, rob the uplifted mass of its complementary ridge of grit on that side, and induce a westerly slope right across the axis of the anticline.

Among the Carboniferous rocks, structure, as we have just seen, played a more important part than composition. In the enveloping red rocks of the Trias, structure has had little to do, composition almost everything, in governing topographical outline. Apart from the red sandy and dry nature of the soil furnished by the rocks of this vastly newer system, anyone only slightly acquainted with geology would at once conclude, from the peculiar softly-moulded outline of the hills on the south-east, southern and south-western margins of the coalfield, that they were fashioned out of a different class of rocks. The contrast is indeed sharp between either the bleak moorlands in the north and north-east, with their long, sharp ridges of Millstone Grit, or the long, monotonous slopes of the coalfield, and the beautifully-wooded, gracefully-outlined hills round Moddershall, Whitmore, Maer and Ashley. Hill and dale here but rarely correspond to the inclination of the strata; sub-aerial denudation has alone determined the landscape. From this cause the lowest members of the Trias, from their superior relative hardness, overlook the central portions of the coalfield; but on the west, from their being depressed by faulting and overlain by the soft, superficial deposits belonging to the Glacial Epoch, they do not appreciably rise above the level of the Cheshire Plain; and, indeed, if the glacial deposits were cleared away, they would be found lying in a broad, deep hollow not much above sea-level, and in places sinking below it.

Yet another type of scenery is met with—the broad, monotonous plain on the western side of the coalfield—composed exclusively of wide spreads of brown unstratified clays, sands and gravel, to which the elevated ground of the Pottery Coalfield forms the margin. In the southern portion of the plain low mounds and hills of mild declivity, with here and there a narrow water-channel almost choked with bramble and hazel, diversify the landscape; but northward the ground gradually sinks into the monotonous plains around Crewe. This gentler type of scenery

has been fashioned entirely out of the sands, gravels and clays of the Glacial Epoch.

River Systems and Streams.—The river Trent, whose head waters are formed by the surface drainage and springs issuing from the Millstone Grit north of Knypersley, constitutes the main drainage channel of the coalfield. After flowing nearly due south in a valley excavated in the shales below the Millstone Grit, it suddenly turns due westward near the Lion's Paw, and enters a narrow gorge excavated in hard massive grits. It then pours itself into the deep hollow occupied by Knypersley Reservoir, from which it issues as a stream flowing due south. Receiving thence many small tributaries from either side of the syncline, it runs in a broad valley through the coalfield, and passes out of the district as a river of some considerable volume, about a mile and a half south of Barlaston. (Fig. 1, p. 6.)

Within the coalfield the majority of the streams flow in deep broad valleys, many of them occupied by numerous industries. Most of them, therefore, lack picturesqueness, especially those excavated in the soft rocks of the Coal-measures. The lesser valleys cut in the surrounding and readily moulded Triassic rocks can lay claim to considerable beauty, but here ordinary atmospheric weathering has accomplished more than stream erosion.

West of the main drainage channel the Staffordshire anticline constitutes part of the main watershed of central England. This is well defined from Mow Cop to Keele, but south of this point it becomes less conspicuous, and in the broad valley between Madeley Road Station and Whitmore Station, the Meece and Checkley Brooks, which join the Trent and Mersey, start close together in the same peat bog, the line of the water-divide being hardly recognisable. Further south the anticline ceases to form the water-parting, the River Tern rising as a strong spring near Maer Hall, cutting completely across it, and thence flowing southward towards the Severn.

We have now traced the line of the main watershed towards the southern portion of the coalfield. In the extreme south at Maer it lies to the east of the anticline. Crossing this somewhat obliquely between Baldwin's Gate and Madeley Road Station, it afterwards coincides with the anticlinal uplift to a little north of Kidsgrove, whence it swerves eastward across the northern half of the Biddulph trough. After crossing the Millstone Grit ridges on its eastern side it is continued athwart the depression intervening between these and the anticline of Lask Edge, and thence over the northern part of the Rudyard Valley. On the northern side the drainage belongs to the Dane and Wheelock; on the south to the Trent and Churnet.

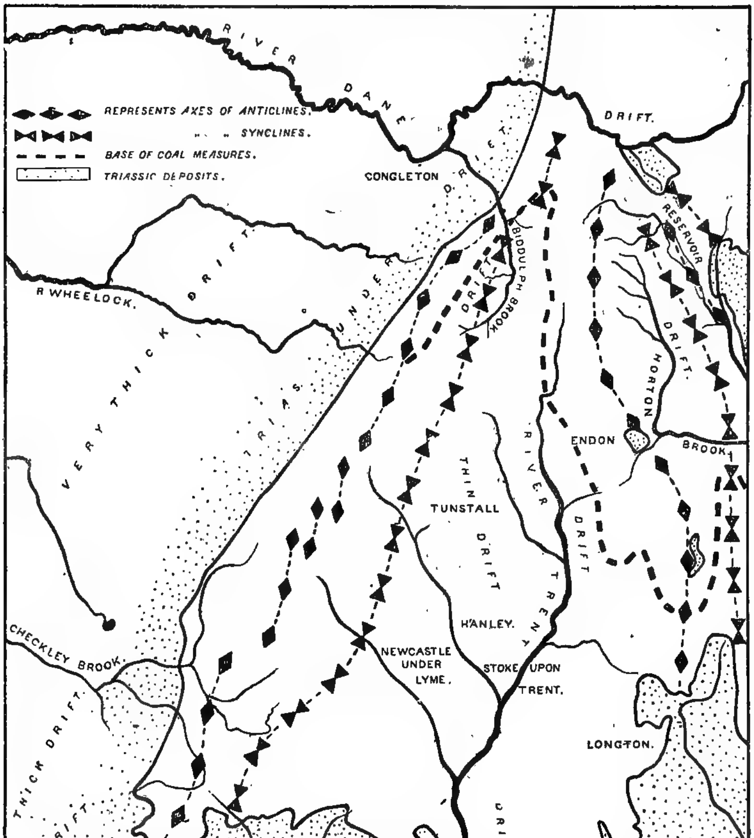
Of the minor valleys in the northern region the most striking are the numerous cloughs—deep, narrow, and often ramifying drainage channels, almost invariably well wooded—which fringe the main stream-valleys. Whether seen from the valley, or viewed from the surrounding hills, they are among the most

noticeable features of the landscape. Those most characteristic of the district, are short, ramifying, clean-cut gorges, increasing rapidly in depth till they reach the level of the main streams. Their rapid descent and striking appearance in the Biddulph

FIG. I.—MAP SHOWING THE RELATION OF SURFACE DRAINAGE TO GEOLOGICAL STRUCTURE.

BY W. GIBSON.

Scale, one Inch=4 miles.



Valley are due to the thick beds of drift-sand, which level up the northern part of the old pre-glacial hollow against the sides of which they are banked. The main stream-valley is cut down nearly or quite to the bottom of the Drift. As soon as the smaller brooks and rills enter this thick deposit they rapidly

excavate deep steep-sided ravines in the soft sand down to the level of the principal stream; before reaching which they are usually joined by several smaller cloughs, many of them now dry.

Alteration of Drainage.—The drainage systems hitherto considered are such as we see them to-day. Their past history has now to be traced.

As previously stated (p. 3), anticline and syncline govern the main direction of present surface waterflow, and there is no doubt that they did so when the Carboniferous rocks were exposed to atmospheric agencies throughout the long unchronicled period preceding the New Red Sandstone. A cursory glance at a geological map, however, shows that many of the streams and rivers have picked out for themselves erratic courses within the main anticlines and synclines. This is nowhere more pronounced than in the case of the Trent, Churnet, and the southern tributary streams of the Dane Valley system. In the first-mentioned river system the most conspicuous features calling for explanation are, firstly, the deep gorge at Knypersley cutting across the Millstone Grit, and extending westward across the Coal-measures to near Mill Hay, where it turns northward and opens out into the main Biddulph Valley; and secondly, the gorge at Stockton Brook, and the broad valley south of this point, in which the Trent wanders diagonally across the strike of the Coal-measures, irrespective of the relative hardness or softness of the rocks. In the case of the Churnet system, the Stockton Brook, a tributary of the Churnet, cuts across the Endon-Werrington anticline, and the northern portion of the Shaffalong syncline at Wall Grange, while the valley of the Horton Brook drains southward to join the Stockton Brook near Endon; but a little south of Horton it is joined by a broad, dry, deep valley, trending due east and west, and cutting completely across the massive grits. Again in the Dane system the small Biddulph Brook, instead of draining down the trough of the syncline, flows in an opposite direction, across the elevated margin of the basin, and cuts a deep gap through the grit-ridges at Mossley. Present circumstances cannot account for these anomalies, but a ready explanation is afforded by a study of the geological conditions which, since Carboniferous times, existed within the area. In pre-triassic times the broad structural features of syncline and anticline dominated the drainage. At this period the main drainage would be westward and southward—westward generally off the main Carboniferous uplift, southward along the synclines—when the main Trent and Churnet Valleys would be excavated. During the Triassic period, as shown by the existing outliers of Trias at Endon, Rownall, Seabridge, and the red sandstone in the Churnet Valley, this older topography was obliterated. Whether or not the later mesozoic strata ever overlay the district is open to doubt, but a platform was formed on which a fresh drainage system was inaugurated, which bore little or

no relation to the pre-triassic landscape. To the streams starting on this platform, the deep gorge at Knypersley, the valley of the Stockton Brook, the dry valley south of Horton, and the Mossley gap can be attributed. Ultimately the older and broader features of the pre-triassic landscape were restored by the sweeping away of the Triassic deposits; but the rivers continued to flow in the gaps made by the post-triassic drainage, and only partially regained their older courses. The great antiquity of some of the valleys of Derbyshire and Staffordshire strongly impressed Jukes who says—"the New Red Sandstone running up the valley of the Dove and lying for several miles along that of the Churnet, following their windings, and resting with its horizontal beds against their broken and eroded banks, shows in the most striking manner that the Carboniferous rocks had been elevated and disturbed, and these valleys had been scooped out in them, before the deposition of the New Red Sandstone."*

At the commencement of the Glacial Epoch the landscape was much the same as we see it to-day, the result as we have just seen of a post-triassic drainage superimposed on a much older pre-triassic denudation. Minor changes however, resulted from the material left behind by the ice, and also from the barriers of ice itself.

As an instance of a recent water divide that of the present course of the Stockton Brook affords a good example. The alluvium of this valley narrows suddenly near Stockton Brook Station on the west, and Wall Grange on the east, where the Millstone Grit crosses the valley. In pre-glacial times, as before-mentioned (p. 7), the water which now flows eastward passed westward through a narrow gorge at Stockton Brook, and entered the main valley, drained by the Trent. The gap at Stockton Brook became dammed with sands and clays left behind by the ice, while the water was held up to the east by the grit barrier at Wall Grange. A lake was thus formed in which the extremely fine alluvium of the Endon Valley was deposited, and whose waters escaping over the grit ridge at Wall Grange gradually excavated their present channel. A good example of the obliteration of the former course of the Trent is seen at Bucknall, where the abrupt manner in which Bucknall Hill, with its steep northern scarp standing out from the surrounding low ground suggests undercutting by river action. At the Hanley and Bucknall collieries the Drift is 81 feet thick, making the pre-glacial surface 366 feet above Ordnance Datum. The Trent between Abbey Villas and the railway bridge to the north flows in a shallow cutting, the surface of the water being between 390 and 400 feet above Ordnance Datum, or at a higher level than the pre-glacial surface at the Hanley and Bucknall collieries. It is evident, therefore, that in pre-glacial times the river flowed more to the east and swept against Bucknall Hill.

* The Analyst, Vol. ix., 1839.

Further examples of drainage changes are furnished by broad valleys, such as those of the Tern from Blackbrook to Willoughbridge, the upper part of the Madeley Brook, and others which are cut in solid rock, but are now occupied by comparatively insignificant streams flowing generally between west and north. These streams on leaving their rock-bound channels are usually somewhat diverted and meander in much smaller valleys eroded entirely in Drift, only increasing in size after the streams have traversed a large area of the drift-plain. The natural inference is that the ice-sheet obliterated the lower courses of the old valleys; and that subsequently new channels were excavated, frequently with a change, sometimes with a complete reversal of direction, below the points at which the Drift blocked these old valleys.

To give examples, the Tern from its source flows west-north-west to Willoughbridge in a wide sand-filled valley excavated in Bunter and Coal-measures. Thence it flows south of west with sandstone-features on its south side, and a broad spread of low-lying drift-sand to the north. It receives all the southward drainage from the high drift-ground of Onneley and Woore. A little further west it crosses the mouth of the short, but broad and deep valley of Winnington with a flat floor of sand and gravel. At Bearstone Mill it traverses the ridges of Keuper Sandstone by a somewhat narrow and deep valley. Thence it swerves south-west to Market Drayton in a channel often bounded on one or both sides by steep cliffs or banks of sandstone, with all the appearance of comparatively recent excavation.

At Aston, a valley of considerable size, but drained by an insignificant stream, is cut westward through Bunter hills, and is then lost in Drift, its drainage being diverted south-westward into the Tern.

The broad and deep valley running westward from Madeley Road Station by Astoncliff is completely blocked to a height of more than 400 feet on the west by Drift, which forms a water-parting between an easterly drainage down the valley and a westerly one into the Tern. This valley could scarcely have been excavated by an eastward drainage, for it has a very small gathering ground on the west, and must have had none at all on that side before the Drift was deposited. It is confluent on the east with the upper part of the Madeley Valley which is a large broad valley with a flat sand-filled bottom. This receives tributary valleys from all sides but the north-west. The basin is bounded entirely by solid rock on the east and almost entirely on all other sides but the north-west. The drainage of the southern and lower part of it is diverted westward by the Madeley Brook, which escapes through a very broad drift-filled gap in the sandstone hills. The northern part drains west-north-west by the Checkley Brook through a deep and comparatively narrow channel cut across hills of Bunter.

The conditions in the district are ideal for the formation of glacial lakes. The north-easterly uplift of the sandstones

along the anticlinal axis determined a drainage in an average north-westerly direction on to the lower ground of the Keuper Marl. The ice advanced in an opposite direction, choking the lower courses of the old valleys, and leaving a line of drift-hills parallel to the sandstone outcrop. During the later stages of the glaciation, as the ice melted off the high ground of the sandstone tracts, a large volume of water poured into the old valleys, and was impounded amongst the hills by the barrier of Drift and ice still blocking the lower parts of these valleys. Sand and gravel were washed down into these lakes, and deposited in a flat or slightly sloping bed on their floor, in a manner strongly contrasting with the general habit of the moundy sand and gravel on the outer part of the main drift-plain.

The Winnington Valley, the Blackbrook - Willoughbridge Valley and the low sandy ground to the north of them probably made one continuous lake, for the formation of which the rock-features on the east, south and west, and the barrier of high Drift on the north were alone sufficient. In fact, if the narrow outlet of the Tern across the strike of the Keuper Sandstone at Bearstone Mill were closed, a lake of considerable size would again be produced in this basin. The position and form of the present valley of the Tern from Bearstone Mill to Market Drayton warrant the supposition that this part of the river valley was initiated as an over-flow outlet for the impounded waters of the glacial lake, and that the pre-glacial course of the drainage was, at any rate for some distance, northward. Mr. Taylor, of Market Drayton, called attention to a deep winding sand-filled channel traced from Market Drayton by Norton-in-Hales. This may, perhaps, have been an earlier course of the Tern flowing in a larger loop round the northern end of the ridges of Keuper Sandstone.

The basin of the Madeley valley and its tributary valleys was clearly a glacial lake. The Drift which fills the wide gap in the Bunter hills on the west evidently marks the barrier, through which the Madeley Brook has cut a narrow channel. If this outlet, the rock-bound channel of the Checkley Brook, and the narrow passage occupied by the south end of Craddocks Moss, which drains into the Madeley Valley, were blocked by Drift or ice, the basin would form a large lake. While the glacial barrier stood at an altitude of 380 feet or a little less, the overflow would be southward by way of Chorlton Moss into the Trent system; thus perhaps accounting for the narrow channel which connects the peat-filled valleys north-west and south-east of Whitmore Station, in which neighbourhood the peat-moss is the watershed between a northerly and a southerly drainage. When its dam of ice and Drift sank lower, the Madeley lake would find an outlet northward or westward; and it is probable that the present channel by which the Checkley Brook drains the northern part of the valley across the Bunter

hills, marks its outlet. Later, as the ice receded, the old drainage, through the broad drift-filled gap a little further south, was re-opened; and by it the Madeley Brook carried off the waters of the southern part of the valley, as it still does.

East and south of Audley a continuous drainage valley is cut in Coal-measures. North of Ougherwall the small stream which occupies this valley flows north, while south of that locality the drainage is southward. A reversal of drainage has evidently taken place here, probably caused by the presence of Drift.

It is probable that several other lakes were formed where gaps in the sandstone hills open towards the north-west or north, and it may well be that one such existed between Harecastle and the south end of Mow Cop. There can be little doubt that the north-western part of the Biddulph Valley was converted into a lake in the later phases of the ice-age by the damming of the gap in the grit ridges at Mossley; and that the mass of sand, which there underlies thin Boulder-clay, was washed out and deposited on the floor of this lake. The deposit of Drift-sand, which wraps round the ends of the grit-ridges on either side of the Mossley gap, as also round the south end of Mow Cop, is difficult to explain otherwise than on the supposition that it was washed down into a body of water. That the material out of which the sand was formed was in part at least introduced into the valley by the ice, and not wholly derived from the degradation of the local grits and sandstones, is proved by the occurrence in it of fragments of marine shells.

The drainage of the Rudyard Valley, though not strictly belonging to the coalfield deserves some mention. This valley is united with that of the Dane to the north by the valley of the Rushton Brook. It is continuous with that of the Churnet to the south-east, and with that of the Horton Brook to the south-west. At the present day the northern continuation of the Rudyard Valley drains into the Dane, the southern end south-eastward into the Churnet, as does also the eastern part of the pass, which traverses the grit-hills between Rudyard and Horton. The western part of this valley drains west into the Horton Brook and finally by way of the Stockton Brook into the Churnet. This transverse valley appears to be blocked south of Horton by Drift which entered it from the north by way of the Horton Brook.

The watershed in the Rudyard Valley is marked by small hummocks of Drift-sand where Beat Lane crosses it north of the Reservoir; while more sand occurs on the slopes of the valley on both sides. Further north also Drift covers the bottom of the valley.

It seems certain that the transverse valley between Rudyard and Horton was excavated by an eastward drainage, and that the northern or Rushton continuation of the Rudyard Valley always drained, as it now does, north-westward. Mr. Barrow has suggested that the southerly drainage of the valley of the

Rudyard Reservoir was initiated as an overflow-outlet for water held up between the ice-sheet which covered the lower ground to the north, and the high ground of the Millstone Grit, that as the ice receded, and the level of the impounded water fell, the drainage deserted the Rudyard Valley and escaped north-westward at a lower level, between the margin of the ice and the high ground, by the present course of the Rushton Brook into the Dane Valley. The case would thus be precisely similar to that of the glacial phenomena lately described by Prof. Kendall, in Yorkshire.* But the Rudyard drainage needs further examination, as this explanation was not in view when the district was surveyed.

* P. F. Kendall, *Quart. Journ. Geol. Soc.*, Vol. lviii., 1902. p. 471.

CHAPTER II.

GENERAL STRUCTURE.

Formations, Groups of Rock and General Geological Structure of the District.

The formations and groups of rock are arranged in the following descending order of sequence, the sedimentary and igneous rocks being kept distinct :—

Table of Formations.

Sedimentary.

Pleistocene and Recent		Recent and Post Glacial	Alluvium. Peat. River gravels.
		Glacial	Clays, sands, gravels, and erratic blocks.
Trias		Keuper	Marl. Soft flags and building-stones.
		Bunter	Sandstones and conglomerates.
Carboniferous	Coal-Measures	The Red and Grey Series	Red sandstones and marls (Keele Group). Grey sandstones and marls (Newcastle-under-Lyme Group). Red marls and green grits (Etruria Marl Group). Grey shales and marls, thin coals and bands of Blackband Ironstone (Black Band Group).
		The grey or chief coal-bearing series	Grey shales, sandstones and marls, with numerous seams of coal and clay-ironstones in upper portion.
	Millstone Grit		Grits and shale.
	Pendleside Series		Grits, Crowstones and shale.
	Carboniferous Limestone		Massive limestone, with shale and thin beds of limestone at top.

Igneous.

A. Interstratified, or contemporaneous with the formations among which they lie.

Tuffs and agglomerates in the upper part of the Carboniferous Limestone.

B. Intrusive, or subsequent in date to the formations among which they lie.

Basalt and dolerite in dykes traversing the Carboniferous and Triassic formations.

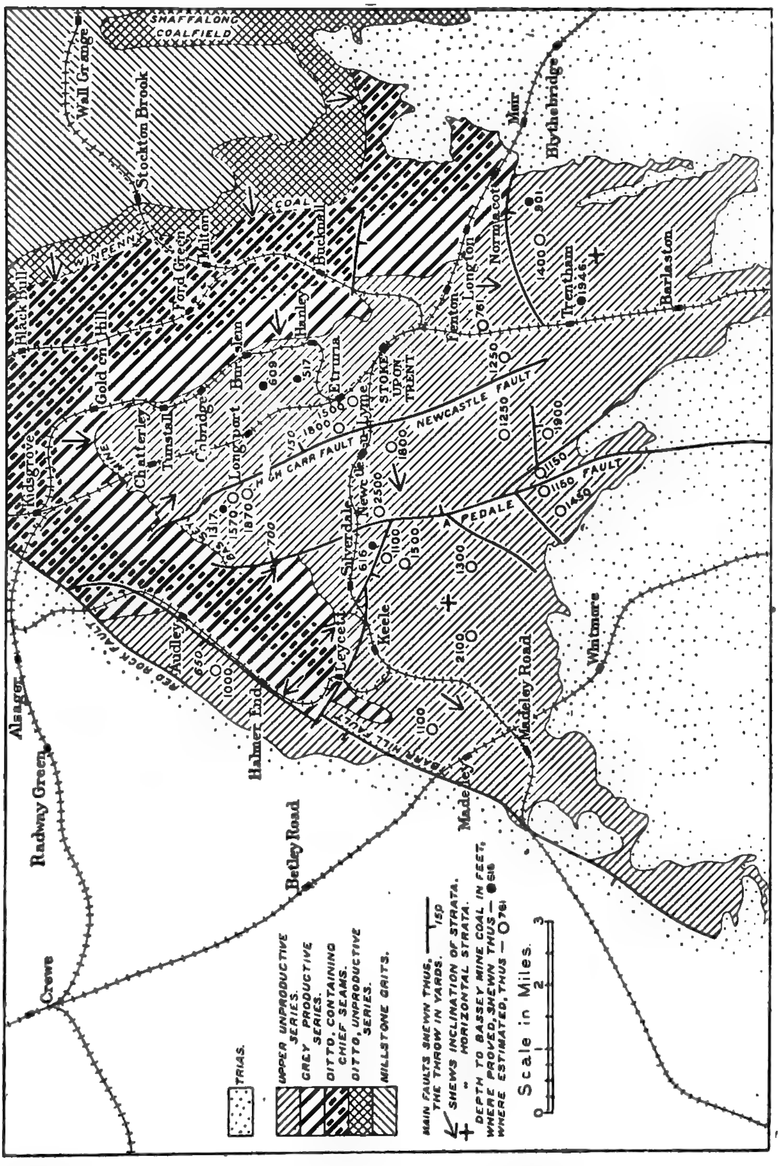
The district occupied by the coalfields of North Staffordshire is situated at the south-western termination of the Pennine Chain—so well known as forming the backbone of central England. This elevated tract, though consisting in the main of one great anticlinal uplift, of which the core is composed of the periclinal Carboniferous Limestone massif of the Derbyshire Hills, and off which newer Carboniferous rocks continue to succeed each other, until on its eastern flanks in Derbyshire and on its western flanks in Staffordshire the Coal-measures of the respective coalfields crop out, is in reality made up of several lesser anticlines constituting in modern technical language an "anticlinorium." It is within the troughs between these saddles that the Coal-measures constituting the Cheadle, Shaffalong and Pottery coalfields, and the smaller basin of Goldsitch Moss, have been preserved. Moreover, the shape of the fold has determined that of the coalfields. Thus the Cheadle Coalfield is somewhat oval in shape; that of Shaffalong long and narrow; while the Pottery Coalfield is of a triangular form owing to the fold contracting rapidly in the north and widening out in the south. To this basin there succeeds on the west side of the coalfield a conspicuous anticline composed of Coal-measures in the south and of Lower Carboniferous rocks in the northern part of the district. (Fig. 2., p. 15.)

The area, especially the Pottery Coalfield, has been further complicated by numerous dislocations, frequently of very great magnitude, which, it will be observed, do not affect the overlying Triassic rocks to anything like the same extent. These disturbances consist, on the east side of the Pottery Coalfield, of a belt of highly-inclined strata bordering the coalfield, and ending at Hulme in a series of fractures which depress the Coal-measures over 200 yards to the east; in the central portion of the coalfield, the Apedale Fault, which at one spot attains the magnitude of over 600 yards, plays a still more important part in the coal-mining industry of the district by introducing a broad belt of barren measures beneath which the coal-seams lie at considerable depths; while on the western side a fault of even greater magnitude extends along the whole length of the district, and for the present forms the limit of all coal workings in this direction.

Between the closing of the Carboniferous and the opening of the next geological epoch—the Trias—a vast interval of time

FIG. 2.—INDEX MAP OF THE CENTRAL PORTION OF THE POTTERY COALFIELD.

BY W. GIBSON.



elapsed, of which the extent will be realised when it is stated that the major part of the folding and faulting took place before

the newer formation was laid down. In addition, huge masses of Carboniferous strata were removed; and it is on the denuded edges of these frequently highly-inclined rocks, or in the deep hollows worn into them, that the red rocks of the Trias resting indiscriminately on the older formation were almost horizontally deposited. Such is the disposition of the Red Rocks on the eastern and southern margins of the Pottery Coalfield; but on the west the junction of the two systems is, for the most part, a clearly-defined line determined by the fault previously mentioned.

In the following descriptions the stratified formations are taken in stratigraphical order, beginning with the oldest.

CHAPTER III.

THE CARBONIFEROUS ROCKS.

Historical Outline.—The history of research among the Carboniferous rocks of North Staffordshire has been characterised by brief periods wherein great advances in knowledge have taken place, separated from others of long interval during which active research remained in abeyance.

The district emerges from obscurity in 1686 in the quaint writings of Dr. Plot, the historian of Staffordshire. His writings abound in traditional ignorance, which remains unbroken till toward the early part of last century. The study of the geology of the Carboniferous rocks in and around the Pennine Chain, from personal observation and not from hearsay, then commenced in earnest. In this great undertaking no name stands out more prominently than that of Farey. He distinguished in the main the great groups of the Carboniferous System, naming them in descending order: the Coal-measures, Gritstone and Shale Strata, Great or Limestone Shale, and Limestone Strata; but up to as late a date as 1839, the accounts of the geology, excepting the brief notice of Conybeare and Phillips, were of a vague character.* In this year, however, Beete Jukes delineated the structure in a masterly sketch, in which the main anticlines and synclines are faithfully represented in his diagrammatic sections, while the text contains a shrewd insight into the succession of the strata.† In this, and in similar popular accounts of the Geology of Derbyshire and Leicestershire Farey's sub-divisions of Mountain Limestone, Limestone Shale, Millstone Grit, and Coal-measures are adopted. At the same time, Jukes clearly upheld the undivided nature of the great Carboniferous System, for in the accompanying article on the Geology of Derbyshire (p. 25), he says: "The whole of Derbyshire, then, is based on Mountain limestone, which, after forming the surface of the districts before described, sinks down on every side, and is covered by coating after coating of the superior rocks, the Limestone shale, the Millstone Grit, and the Coal-measures. All these are always conformable to each other, each dipping (in the same places) in the same direction and at the same angle, and being, in fact, only different parts of one compact and continuous mass of rocks, all the four insensibly melting, as it were into one another, and forming one whole."

* Outlines of the Geology of England and Wales, 1822.

† *The Analyst*; a Quarterly Journal of Science, Literature, Natural History, and the Fine Art., vol. ix. (1839), pp. 233–240.

Jukes' sketch strikes the keynote of the geological structure; but a few years previously (1835) a considerable number of fish remains, from the Coal-measures at Silverdale, described by Egerton,* had attracted the attention of geologists; and from this date onward the small Pottery Coalfield has continued to yield this class of organism in great abundance.

The first comprehensive map of the district accompanies the account by Dr. Garner in his Natural History of the County of Stafford, published in 1844.† Essentially a naturalist, Dr. Garner, nevertheless, paid much attention to geology, more especially to that of the northern part of the county. On his map the separate coalfields are correctly indicated; the inlier of Carboniferous Limestone at Astbury, and the outcrop of the Millstone Grit, in which is included the Limestone Shale of Jukes, are also noted. In the map of Ormerod, the Millstone Grit and Coal-measures are grouped together.‡

The two editions of the Geological Survey Map (Sheet 72 N. W.), include the larger portion of the Pottery Coalfield, and show the progress of enquiry. In the first edition, published in 1857, the Coal-measures are carried down to the Third Grit, north-west of Bagnall; and the Millstone Grits down to the shales with earthy limestones of Onecote. In the second edition, published in 1864, the grit bands are mapped out by Professor Green, the base of the Millstone Grit being now drawn at the bottom of the Third Grit in the south-eastern area and at the Fifth Grit in the north-eastern region. The beds below these grits are termed Yoredales, in which sub-division the great thickness of shales and grits above the shales of Onecote are included. The two editions thus plainly indicate the difficulty experienced in drawing a divisional line in the strata below the Third Grit.

The first classification of the Coal-measures accompanies the description of the iron ores§, and groups the strata into Upper Measures, Pottery Coal and Ironstone Measures, Lower Thick Measures and Lowest Measures—a classification adopted, with slight alteration, by subsequent observers, but which recent investigation does not justify.

As regards the mapping of the outcrop of the seams of coal and ironstone and the delineation of the faults and folds, the work

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* On the discovery of Ichthyolites in the south-western portion of the North Staffordshire Coalfield. *Proc. Geol. Soc.*, vol. ii., No. 41 (1835), p. 202.

Natural History of the County of Stafford. London, 1844.

Outline of the principal Geological features of the Salt-Field of Cheshire and the adjoining districts. *Quart. Journ. Geol. Soc.*, vol. iv. (1848), p. 262.

§ Iron Ores of Great Britain. Part iv. *Mem. Geol. Survey*, 1861.

of the survey was anticipated by the excellent map of W. S. Cope, published in 1852*. Constructed at a time when the upper seams of coal and ironstone were being extensively worked, this carefully prepared map proves of value to-day.

From the year 1860 to about 1890 geological work in North Staffordshire was mainly confined to palæontological research, the results of which were published by Mr. John Ward†.

In 1890 the progress of research may be said to have entered on a fresh period of activity, largely in connexion with the Geological section of the North Staffordshire Field Club, which, from its foundation in 1866 has always shown a keen interest in the geology of the district.

Carboniferous Limestone and beds below the Third Grit at Astbury.

By W. GIBSON.

Traced northward, the western anticline north of Harecastle is made up of the Lower Coal-measures until it enters the obscure ground a short distance south of Grotto Wood, where a fault of considerable magnitude throws down the western limb. On the upthrow side of this fault the anticline again emerges, bringing in the shales many feet below the Third Grit in Grotto Wood, and finally the top beds of the Mountain Limestone in the old quarries of the Astbury Limeworks. The crest of the narrow dome has here been quarried away, but the limestone is being extracted by underground galleries reached by an adit commencing in the Drift deposits north of Baytree Farm. The narrow dome structure is, however, very evident, though the western half is partially truncated by the Red Rock Fault. The underground workings remove the topmost beds of the limestone, which are of a light colour, massive and very similar in character to the great bulk of the Derbyshire limestone. The fossils are of the usual Mountain Limestone types, including *Productus, Chonetes papilionacea.* A bed over four feet thick is made up of *Lithostrotion Martini.* The rock is burnt for lime or converted into cement. In the quarry the limestone passes up into calcareous shales with thin beds of limestone, which in turn are overlaid by dark shales, with a coal-seam 1 foot 6 inches thick. Some old shafts situated on the south side of the stream running along the boundary of Limekiln Wood also reached the limestone, but at what depth could not be ascertained.

* Mineral Map and Sections of the North Staffordshire Coalfield. Hanley, 1852.

† The Geological Features of the North Staffordshire Coalfields; their organic remains, etc. *Trans. North Staff. Inst. Min. Eng.*, vol x., 1890.

At the northern end of the quarry a cliff face, about 30 feet in height, immediately attracts attention. On examination it is found to be composed of angular fragments of green tuff, often vesicular, embedded in a greenish calcareous matrix, and evidently of volcanic origin. Fragments of marmorized limestone are not infrequent, and in some places there are corals and other fossils roughly occupying certain layers in the mass. Two varieties of agglomerate occur. The harder variety Mr. Arnold Bemrose describes as a basalt tuff. "The lapilli are in a remarkably fresh state of preservation. They contain olivine phenocrysts altered to calcite and sometimes to serpentine, with augite and felspar in a yellow isotropic base. The augite is fresh, and occurs in idiomorphic crystals and prisms, often arranged in groups or clusters. The felspars are fresh and clear, and have a sharply-defined outline. A few small vesicular and non-crystalline lapilli are present. The lapilli are cemented together by a limestone-paste, in which occur Foraminifera and other organisms, together with a few fragments of augite and felspar and a subangular quartz-grain." The same writer describes a softer variety met with, as being composed of "fragments of dolerite in a limestone-paste containing veins of calcite and traces of organisms."*

South of the cliff a gap of 150 feet occurs in which no rock is visible. Then comes an exposure of limestones and calcareous shales with interbedded tuffs on the same strike with the agglomerate. The general appearance suggests that the agglomerate in the cliff section occupies the site of a vent, but the stratigraphical evidence obtainable at the surface or in the underground workings is not conclusive. That the volcanic activity was displayed during the close of the Carboniferous Limestone period is shown by the interstratified tuffs south of the cliff section (fig. 3, p. 22). This is still more forcibly demonstrated by the following section measured in a small brook running east and west about 250 yards north of the quarry, and cutting completely across the northern end of the dome, thus revealing the strata on either side of the saddle:—

BROOK SECTION SHOWING INTERBEDDED TUFFS AND LIMESTONE.

Character of Strata.	Thickness, Ft.	In.
Tuffaceous limestone - -	4	0
Gap, a few feet.		
Thin coal - -	0	5
Hard calcareous nodular rock - - -	0	3

* On the Agglomerates and Tuffs in the Carboniferous Limestone Series of Congleton Edge, by W. Gibson and Dr. Wheelton Hind. *Quart. Journ. Geol. Soc.*, vol. lv. 1899. p. 556.

Character of Strata—*continued.*

	Thickness. Ft.	In.
Gap	2	6
Flaggy calcareous sandstones passing into shale	5	0
Productus, and crinoidal limestone	1	2
Black shales, with nodular concretionary limestone	3	0
Crinoidal limestone	1	3
Tuffaceous limestone	8	0
" "	1	9
Tuff much decomposed; no fossils, exposure obscure towards bottom	120	0
Gap	130	0
Coarse tuff, with fragments of limestone	100	0
Tuffaceous limestone, with fossils	2	0
Well-bedded calcareous tuff	6	0
Massive limestone	3	0
Hard tuff	8	0
Tuffaceous limestone	0	8
Well bedded calcareous tuff	1	11
Thin hard tufaceous limestone	0	2
Tuff	1	0
Hard limestone	3	0
Gap	12	0
Tuffaceous limestone	2	0
Tuff coarsely laminated	5	0
Limestone passing into calcareous tuff	2	6
Yellowish-brown tuff	+6	0

This does not show the true thickness of the individual beds, but only the width of outcrop, for along much of the distance the stream closely follows the strike—being exactly coincident with it on the horizon of the coarse tuffs. Near the termination of the section the strata are thrown into numerous gentle folds.

This occurrence of contemporaneous volcanic action towards the extreme summit of the Carboniferous Limestone is of much interest; since at Tissington volcanic activity was also prevalent towards the close of the Limestone period, and elsewhere along the Pennine axis within the Limestone area of Derbyshire.

The tuff beds and thin crinoidal limestones of the Astbury inlier are succeeded by a considerable thickness of shales and interbedded grits formerly termed Yoredale, but for which the term Pendleside Series has been suggested by Dr Hind.* Strata of a

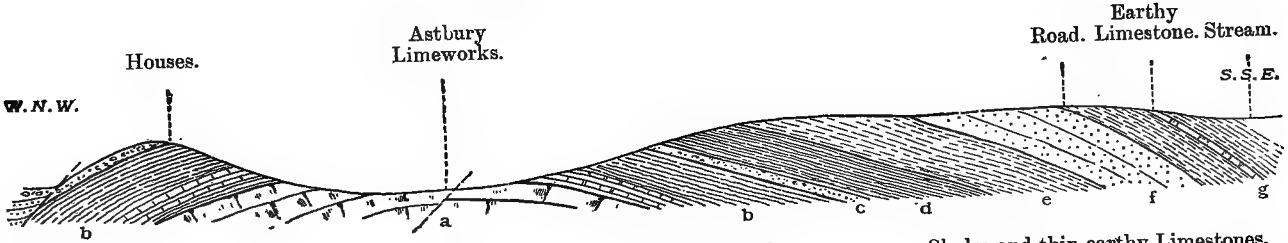
* Quart. Journ. Geol. Soc., lvii., 1901., p. 368.

FIG. 3.—*Section across the Carboniferous inlier of Astbury,*

(From *Quart. Journ. Geol. Soc.*, vol. xlv., 1899).

By W. GIBSON.

Scale horizontal and vertical 25 inches = one mile.



a Limestone.
Shales and thin Limestones.

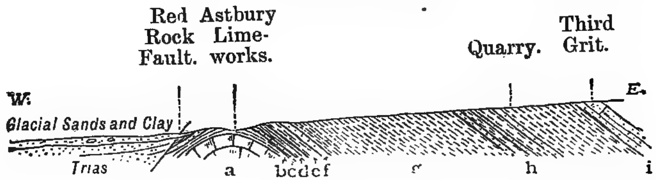
c Tuff.
d Shales.

e Shales with Coal.
f Grit.

g Shales and thin earthy Limestones.

FIG. 4.—*Section across the Beds below the Third Grit on Congleton Edge.*

Scale 6 inches = one mile.



a Limestone.
b–f Shales, Limestones, Agglomerates, Tuffs and Grit.

g Shales and thin earthy Limestones.
h Shales and Grit
i Third Grit.

similar character invariably underlie the Third Grit along the borders of the Pottery Coalfield, but the only spot where the lower beds are visible is in the vicinity of the Astbury inlier. By means of the sections in the mountain road leading from Limekiln Farm, and in the streams flowing down from the edge along the northern margin of Limekiln Wood, the following nearly complete sequence between the Carboniferous Limestone and Third Grit can be obtained.

SECTION SHOWING THE SUCCESSION OF THE BEDS BETWEEN THE CARBONIFEROUS LIMESTONE OF THE ASTBURY INLIER AND THE THIRD GRIT ON CONGLETON EDGE. (FIG. 4 p. 22).

Character of Strata.

	Character of Strata.	Thickness. Ft.	In.
	Third Grit :—		
PENDLESIDE SERIES.	Dark shales with band containing *Goniatites*	450	0
	Grit with red spots	20	0
	Shales -	35	0
	Grit - -	8	0
	Shales (approximate thickness)-	150	0
	Grit	9	0
	Shales -	8	0
	Grit - -	5	0
	Shales (approximate thickness)-	30	0
	Grit -	9	0
	Shales	80	0
	Grit	8	0
	Shales	30	0
	Grit- -	12	0
	Shales ? not well seen	50	0
	Thin flaggy sandstones	50	0
	Sandy shales - - - -	45	0
	" " with thin beds of grit - - -	20	0
	Dark and grey shales with hard bands—about -	250	0
	Black limestone with *Goniatites*	7	0
	Shales—about	50	0
	Hard grit with red spots—about	70	0
	Shales—about - -	50	0
	COAL- -	1	6
	Shales	3	0
	Calcareous shales, crinoidal limestone.		

Total 1,450 feet about.

Many of the grit bands can be traced for several hundred yards to the north east. In this direction, about a mile distant from Limekiln Wood, a quarry situated between 500–600 feet below the Third Grit, affords the following interesting section :—

QUARRY BELOW THE THIRD GRIT NEAR THE ROADSIDE LEADING FROM GILLOW HEATH TO CONGLETON.

	FT.	INS.
Dull grey and yellow clay, with grit blocks -	5	0
Rotten limestone, made up of *Orthis resupinata*	5	2
Grit -	1	0
Shales, grey -	3	0
Shales with thin slightly calcareous nodules	0	9
Hard fine grey sandy shales -	0	4
Shales with calcareous nodules, rich marine fauna -	5	7
Rather dark shales with two lines of calcareous nodules	3	0
Shales with *Goniatites* -	0	8
Darker calcareous shales, coarsely laminated, with *Glyphioceras spirale, Posidoniella lævis*	1	0
Shales with calcareous nodules, marine fossils -	4	0
Coal about ½ inch twisted into joints of grit	0	0½
Gannister-like grit -	5	8
Gannister grits and shales with plant remains -	33	7

The fauna of the marine beds is extremely rich, as shewn in the following list given by Dr. Wheelton Hind*:—

Ceriopora (interporosa) Millepora.
Athyris ambigua.
Chonetes laguessiana.
Dielasma hastata.
Discina nitida.
Lingula mytiloides.
—— scotica.
Orthis resupinata.
—— Michelini.
Productus Cora.
—— longispinus.
—— scabriculus.
—— semireticulatus.
Spirifera glabra.
—— trigonalis.
Streptorhynchus crenistria.
Aviculopecten fibrillosus.
Actinopteria persulcata.
Allorisma sulcata.
Ctenodonta lævirostris.
Edmondia rudis.
—— MacCoyi.
Leiopteria squamosa.
Modiola transversa.
Myalina peralata.
Mytilomorpha rhombea.
Nucula gibbosa.
—— æqualis.
Parallelodon obtusus.
Posidoniella lævis.
—— semisulcata.
Pteronites angustatus.
Protoschizodus orbicularis.
Sanguinolites v-scriptus.
Scaldia benedeniana.
Sedgwickia ovata.
Loxonema sp.
Macrochilina sp.
Pleurotomaria monilifera.
Bellerophon Urei.
—— sp.
Ephippioceras bilobatum.
Glyphioceras diadema.
—— spirale.
Orthoceras sp.
Ceratiocaris oretonensis.
Dithyrocaris testudineus.

Although in other areas within the district the same horizon must be intersected in many places by streams and roads, these marine beds have not been discovered. The rocks just described dip at angles varying from 45 to 60 degrees eastward, forming in fact the western limb of the Biddulph trough. They can be traced southward into Grotto Wood, where, as described, they terminate against a huge dislocation which brings them in contact with strata wholly above the Millstone Grit.

* Trans. North Staffs. Field Club. Vol. xxxvi., 1901–1902. p. 78.

Beds below the Third Grit on the south eastern margin of the Coalfield.

By G. BARROW.

On the elevated ground on the eastern side of the coalfield these rocks are brought up by a strong anticline, the axis of which trends roughly north and south from Werrington, through Endon into the high ground separating the Biddulph and Rudyard troughs. The rocks lie at varying angles, and as they are faulted, drift covered, and unexplored by shafts or borings, it is doubtful how much of the thickness on Congleton Edge is represented.

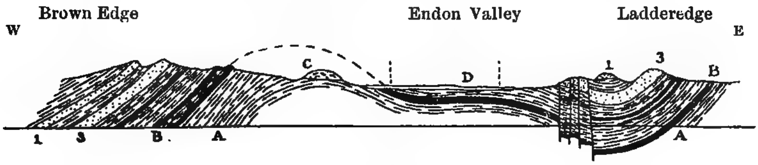
The following groups in descending order of sequence can be recognised.

3. Marly bands (thin) succeeded by dark shales.

2. Crowstone bands and associated marls and fireclays. Stanley Grit at the base.

1. Dark shale with nodules and thin sandy seams.

Fig. 3. GENERALISED SECTION ACROSS ENDON (G. BARROW).



D. Alluvial Deposits.
C. Bunter of Endon Hill.

1. First Grit.
3. Third Grit.
B. Crowstone.
A. Shales.
} Millstone Grit Series.

The crest of the anticline lying between the two outcrops of the Crowstones is formed mainly of dark shales, which attain a considerable thickness to the north of Endon. Good sections of these occur in several places. The best are in the stream and gutter running from Lanehead in a south-east direction to the road on the north side of Endon. The dark shales contain a great number of small plant remains, the mode of occurrence of which is suggestive of leaves falling into comparatively smooth or quiet waters. They further suggest the idea that much of the shale may be due to a process of filtration of coarser material by dense vegetation, which arrested the flow of heavier sand particles, and at the same time supplied the great number of comparatively uninjured fragments of plants. Lower down the hillside the stream cuts through shales containing numerous nodules, but fewer plants and no shells were found in them. The nodules are so numerous in places, and the section is so continuous, that it is worthy of a detailed search.

A good section of these beds also occurs in the little stream on the north side of the road from Lane-end to Brown Edge.

In a disused brickyard, now converted into a garden, on the hillside west of Lane-end and near the top of the opening is a thin, dark, fissile, sandy bed containing *Goniatites* and *Pterinopecten*. They are unfortunately not well preserved, but show how these fossils reappear again and again, as we ascend the series from the Carboniferous Limestone into the Coal-measures.

Above the beds last described are some curious fine-grained sandstones to which the name of Crowstones has been given. These consist of very fine sandy material, which, in the type rock, has apparently been cemented together by the deposition of secondary silica, forming in fact a kind of quartzite Whether or not this is the correct explanation, the bed is intensely hard, and where the outcrop runs in fairly straight lines it often rises out of the softer shales and marls as a low wall or dyke. A specially good example of this phenomenon is seen in the band that crosses the road between Brown Edge and Endon, the rock north of the road being very dyke-like in certain parts of its outcrop. Similar rocks are seen in many places on the hill top above Brown Edge; they also occur south of Hough Wood, above Badderley Edge, and on the other side of the anticline between Rownall Hall and the canal west of Wall Grange.

Owing to their hardness these Crowstones are much used for road-metal on second-class roads. Here and there patches of pebbles, often quite as large as those seen in the Third Grit, are present in the Crowstones; but, usually, the matrix enclosing the pebbles is very fine in grain like that of the normal Crowstone.

While the sandy beds at this horizon are usually of this fine-grained, hard nature, they do not persistently retain these characters; moreover, it is doubtfoul how far any one band is persistent, and it is thus very difficult to fix any horizon in the zone, which is probably one of considerable thickness.

As an illustration of this difficulty the group of Crowstones to the south-west of Wall Grange (Catsedge) may be referred to. A little to the south of Catsedge there are three well-marked bands of Crowstone, containing patches of pebbles here and there. Towards Endon they appear to run together, and, in places, the united mass puts on the appearance of a fine grit. This band is clearly about the same horizon as the grit, which has been quarried at several places near the Ashes to the north of Endon; but the rock here is very different from the rock at Catsedge. Again, the Stanley Grit looks totally unlike the Catsedge rocks, although they are on opposite sides of the anticline, and should be approximately on the same horizon. If, however, the Stanley Grit is followed to the south towards Moor Hall it is seen to split up into several bands closely resembling typical Crowstone, though not so hard or quite so fine in grain, and here there is difficulty in regarding them as the same beds.

The lenticles of pebbles in the Crowstones suggest that, as regards this area, traces of what may be conveniently termed

'grit' conditions are first met with, and the bed locally reverts to a grit here and there. This view is borne out by the evidence from the Ipstones area, where the Crowstones are largely replaced by grits, indistinguishable from the typical coarse bands of the Millstone Grit. It therefore seems probable that the long Crowstone outcrop west of Endon, and the Stanley Grit are approximately on the same horizon, if they do not actually pass into one another.

The beds associated with, and separating the different bands of Crowstones, are more often white and red marls and fireclays than grey and dark shales, though the latter occur at times. Their nature may be seen in the quarry between the two Crowstone outcrops west of Endon. "Smuts" and thin seams of coal occur occasionally, associated with fireclay; and one of these was worked on the south side of Hough Wood, south of Stockton Brook. As far as could be ascertained it was rarely as much as a foot thick, and appears to be of a local nature, for it was only followed for a short distance. In an old clay pit close to Rownall Farm, rather more than a mile north of Werrington, some marly shales lying between two beds of Crowstone contain calcareous nodules with well-preserved specimens of *Goniatites*.

In a great number of cases the shales and marly beds underlying the Third Grit form a curiously flat featureless area; examples of which may be seen above Brown Edge and Badderley Edge, where the dip being moderately high this flat belt parallel to the grit is not very broad. This feature is however, singularly well shown in the southern part of the Millstone Grit area, where the horseshoe-shaped outcrop of the Third Grit encloses nearly a square mile of almost level ground. Though there is some Drift over this area the flatness of the ground is not due simply to that fact, for precisely the same feature occurs where the dips are low in other areas. As a consequence streams crossing such a flat area give few sections, and exposures of this part of the series are distinctly rare. The exact thickness of this portion of the sequence is thus difficult to calculate; and, moreover, occasional lenticles of Crowstone seem to be present, well above the normal horizon for their occurrence.

Experience from adjacent areas shows that there is usually a small seam of coal at the base of the dark shales, which is probably the seam once worked near Greenway Hall above Badderley Edge.

North of Endon the anticlinal axis is well defined by the grit ridge between Knowles Farm and Parkhayes Barn.

The North-eastern margin.

By C. B. WEDD.

To continue the description of these beds northwards, the lowest beds in the district between the Millstone-Grit outcrops of the Biddulph and Rudyard valleys must be those brought to

the surface in the crest of the anticline on Lask Edge, south of the Crowborough Fault. The strata, though no good exposures occur, appear to be shales, with beds of sandstone coming on above; but whether these shales are completely below the whole group of Crowstones, is uncertain. Several beds of the overlying Crowstones, close together, make a good feature in Cliff Wood, south of Hollins, the same beds renewing the feature north of the Crowborough Fault by Broadmeadows and west of Shirkley Hall. These rocks—the Yoredale sandstones of the old map and memoir*—consist chiefly of hard white, grey, purple or red sandstones, mostly fine-grained and thin, but of various thickness, up to as much as 20 feet, with intercalated shales. The sandstones occasionally contain seams of small pebbles. Intensely hard white, quartzitic sandstones or Crowstones also occur, but this phase is less common in this part of the district than elsewhere. The beds are doubtless impersistent, and it is probable that individual rock-bands of the series may pass from one type to the other in a short distance. On the highest ground above High Bent, a hard fine-grained white and red sandstone, with coarse pebbly seams and plant-remains, almost on the crest of the anticline, belongs to the lower part of the group, and may recur in the stream which crosses the feature further east, owing to a probable doubling of the anticlinal crest (see horizontal section, p. 25). Between here and Dingle Brook to the north the outcrops of higher beds of these sandstones successively cross the crest of the high ground, as it falls in that direction, the uppermost beds crossing the brook.

Close to the north bank of Dingle Brook, which affords a good section of the series, north of Ashmore Heath, and near a small patch of drift-sand indicated on the map, a small pit shews the following sequence in what appears to be the highest, or almost the highest, sandstone of this group:—

SECTION IN SMALL PIT CLOSE TO DINGLE BROOK, 350 YARDS SOUTH-EAST OF EARLSWAY HOUSE, AND 300 YARDS WEST OF STONYEDGE, RUSHTON JAMES.

Character of Strata.	Thickness. Ft.	In.
Hard white fine-grained siliceous sandstone, with alternate layers of marine shells (*Orthis*) and plant-remains	0	8
Grey shales, with thin hard siliceous bands and obscure traces of plants - - -	0	10
Hard, light grey fine-grained massive siliceous sandstone, with few shell-casts (*Orthis*) - -	0	6
Grey shales with a thin hard siliceous band -	0	6
Hard light-grey fine-grained siliceous sandstone with thin shale partings and a few shell-casts (*Orthis*) - -	1	0
Hard light-grey massive fine-grained siliceous sandstone containing: Two beds full of *Orthis*-casts, with some *Fenestella*, in the upper part - -; Bed crowded with *Orthis*-casts in the middle - -; Bed with plants, just below - -; Bed, with fewer *Orthis*-casts in the lowest part -	2	0

* *Mem. Geol. Surv.*, Geology of the Country round Stockport, Macclesfield, Congleton, and Leek, p. 17.

In the stream, in a position apparently a few feet below these beds with marine fossils, calcareous nodules in the shales contain fish-spines and *Goniatites.* The strata here lie on the west side of the anticline. On the east side of it the *Orthis*-sandstone was not recognised, but in beds in the same stream south of Rushton Hall, which from their position should be some little distance above the *Orthis*-sandstone, the shales, amongst which occur layers of impure, apparently unfossiliferous, limestone, yielded *Pterinopecten* and calcareous nodules full of small *Goniatites.*

A comparison of the position and sequence of these strata with those of the marine fossil-beds in the gannister quarry, near Congleton Edge, and in the neighbouring stream (see page 24) rather favours the identity of the horizons at these two localities. At first sight it seems that the *Orthis*-beds of Dingle Brook may lie lower in the sequence with regard to the Third Grit than those near Congleton Edge, though the dip of the eastern beds is less. But it must be borne in mind that the Fourth and Fifth Millstone Grits, absent at Congleton Edge, are largely developed not far east of the Dingle Brook section, the Fourth Grit in great thickness, and that both these grits persist some distance west of this section. Probably then the incoming of these grits, with possibly a concomitant thickening of the shales, accounts for the apparently greater distance of the *Orthis*-beds of Dingle Brook below the Third Grit.

Eastward, in the same brook, few, if any, beds of sandstone occur between the strata just described and the Fifth Grit, and shales apparently make up the entire sequence. West of the anticline also there seems to be an absence of sandstone-beds for some distance below the grit at Crowborough (p. 34).

First and Third Grits on the Eastern side of the Coalfield.

By G. BARROW.

The Grits which rise up on the flanks of the eastern anticline (p. 25) have been driven through near Stockton Brook by the Potteries Waterworks Company, and from this level the thickness of the different members of the series has been proved as follows:—

LEVEL (POTTERIES WATERWORKS COMPANY) STOCKTON BROOK.

	True thickness. Ft.	In.
First Grit*	70	0
Black Shale	120	0
Coal - -	1	6
Third Grit - - -	190	0

* It is doubtful if the full thickness was passed through.

The First and Third Grits, resemble one another in being coarse-grained rocks. In the Third Grit the pebbles, as a rule, are more abundant and larger, but the component grains among which the pebbles are set, are distinctly coarse, and of much the same size in both rocks. These grains consist of quartz and felspar for the most part; there is also present a small quantity of decomposed brown mica, a little iron ore, and some white mica. The felspar is often potash felspar, and the rocks have all the appearance of being derived directly from the waste of a mass of granite. Quarries have been opened in the grits at several localities, but the Third Grit appears to be more often quarried than the First. Whether this is due to a natural superiority as a building-stone, or to the fact that it is often more accessible than the First Grit is not clear.

A point of importance in connexion with these grits is their persistence, and the regularity with which they thicken and thin in definite directions. At first sight their extremely false-bedded character would suggest impersistence and rapid variation in thickness, but this idea is founded upon a mistaken notion of what they really are. The First and the Third Grit are not single beds, but a series of interlacing lenticles of grit, which together build up a minor sub-formation, which is just as regular in its thickness as is any one of the sub-divisions of many other formations. The First and Third Grits are persistent, because they are of the nature of a minor formation, and not one bed of grit.

It will be shown that these grits do thicken and thin; but how far this process continues in one definite direction, and how far it is a local phenomenon has not yet been fully established. The grits to the north at the Roaches are both thicker and coarser than at Stockton Brook, and over the rest of the area here described, while further south they become finer and thinner. The change, however, takes place more rapidly in the case of the First Grit than in that of the Third. The area to the south-east, near Ipstones, shows, however, that the thinness is less in that direction than at Stockton Brook; and, moreover, the Grits, particularly the Third Grit, though they are appreciably thinner, largely retain their coarse character.

The shales between the two grits are not often well exposed. Owing to their softer nature they usually lie in a hollow between the grits, and are either covered with the sandy wash from these beds or with drift lodged in the intervening hollow.

The higher beds of these shales are well exposed in the brick-yard at Wall Grange, from which it will be seen that in this section the black shales do not extend from the top of the Third Grit to the base of the First, as represented in the account of the Stockton Brook adit (p. 29), but that the upper part consists of greyer, more sandy, and marly shales, with plant remains. So far as could be seen no *Goniatites* or other marine organisms

occur in them. A considerable mass of darker well-bedded and often laminated shale underlies this more sandy material.

The coal mentioned in the account of the Stockton Brook adit is the well-known Third Grit Coal, which has been worked to a considerable extent about the Roaches to the north, and in the Ipstones district to the east; but, in the area under description, it seems to be always much thinner than in either of the other areas, and has rarely been worked. Underneath the coal at Wall Grange a level was driven near the canal, close to the railway station, in a lenticular seam of ironstone, resembling the Froghall Ironstone in appearance. A considerable quantity of ironstone was taken out, but though of good quality it proved to be too thin and irregular to be worth working. A natural section of the coal seam is met with in a small stream south-east of the village of Bagnall. It is only a few inches thick, and lies close to the top of the Third Grit. In tracing the grits round the anticline no workings in the coal were observed till the neighbourhood of Wall Grange was reached. Here the position of several old shafts may still be traced, but the seam was thin, and has not been worked for many years.

It may be worth noting that elsewhere a hard shale band, with *Goniatites* and *Pterinopecten* in great numbers, generally overlies this coal. It probably occurs in this area also, but it has not been found owing to the absence of sections.

The Third Grit has a clear outcrop over much of the area, it being only near Werrington that it is obscured by Drift, and possibly by faulting.

Large quarries have been opened in these beds both north and south of Stockton Brook, where the abundance of small pebbles in certain parts of the rock can be frequently noted. Quarries also occur at Wetley Moor on the south side of the fault east of Launders Bank.

About 300 yards north of the four cross-roads, north-east of Werrington, an interesting exposure is met with, showing a fairly well glaciated surface beneath the Drift.

At Rownall Hall and about Wall Grange quarries have been opened in this bed on both sides of the stream. The best exposure is that close to the road on the west side of the outcrop facing Dunwood Hall. Some interesting sections also occur in the railway cutting, and in one of these part of the grit is unusually pebbly and incoherent. The rock here admirably illustrates the dying out of a syncline in a number of step faults.

Quarries which show the character and inclination of the beds in the First Grit, have been opened in several places north and south of Stockton Brook. To the north of Stockton Brook the dip averages 30 degrees, but to the south it is much higher; and in a small quarry, recently opened at Badderley Edge, the First Grit is slightly inverted for a short distance. The dip in this neighbourhood is always high—from 40 to 60 degrees or more, but further south it rapidly flattens out. Quarries also occur to

the west of Werrington. Although the village clearly stands on the First Grit the outcrop from Cellarhead to the north is obscure. The beds along both sides of the syncline of Coal-measures forming the Shaffalong Coalfield have often a high dip, and the First Grit makes an evanescent feature, frequently buried under Drift. In addition a fault at the north end of this small coalfield obscures the outcrop. The first distinct outcrop is seen in a quarry a little north of Westwood Manor, where the rock is a good building-stone. Another section is seen at Coalpit Ford north of which it is cut out by a rather large fault.

To the north of Wall Grange the grit has been quarried to some extent and the outcrop is singularly clear, but to the south, while good exposures are occasionally seen, the exact course is very difficult to trace, as the Shaffalong syncline ends off northwards in a great number of small faults.

The First, Third and Lower Grits of the Biddulph Valley,
By C. B. WEDD.

The grit beds, collectively and individually in different degrees, show a strongly marked attenuation both to south and west throughout the district.*

Of the four distinct grits which can be recognised in the north-east of the district, the lowest two seem to have died out, almost or entirely, before reaching the western side; while the highest rapidly diminishes southward from Congleton Edge in the west and appears to die out at Mow Cop. On the latitude of the latter locality at Horton, in the east, all four grits are still present in force, and perhaps only the Fourth shows a decided decrease of thickness.

It is probable that of the lowest two, the Fourth in the north of the district and the Fifth in the south, respectively persist the further westward.

The Second Grit, or Haslingden Flags of Lancashire, has, according to Hull and Green, died out before reaching this district.†

In the absence of opportunity to examine the evidence on which these grits were originally correlated with those further north, and numbered accordingly, the system of numeration in general use for the Millstone Grits of Lancashire is retained, and the four recognisable grit-beds of this region will be described as the "First," "Third," "Fourth" and "Fifth," in descending order.

The southerly and westerly dying-out of the Fourth and Fifth Grits introduces a difficulty in drawing the boundary between the Millstone Grit and the underlying shale-series, and

* For the southerly attenuation of the arenaceous and argillaceous members of the Carboniferous System, see E. Hull, *Quart. Journ. Geol. Soc.*, vol. xviii., p. 137; Hull and Green, *Ibid.* vol. xx., p. 244; W. Hind and J. A. Howe, *Ibid.* vol. lvii., p. 391.

† *Ibid.* vol. xx., p. 261.

serves to show the worthlessness for stratigraphical purposes of such lithological divisions as the Millstone Grit, when not characterised by a distinctive fauna or flora. Thus, in the southern part of the Millstone Grit area the base of that series could not, in the absence of the lower grits, be drawn elsewhere than at the bottom of the Third Grit; while in the northern district it was impossible to exclude from the series the massive Fourth and the Fifth Grits, which probably represent the Kinderscout Grit of Derbyshire, the thickest of the whole series. Hence it arises that the base adopted for the "Millstone Grit Series" is not homotaxial throughout. The same difficulty, though in a much less degree, applies to the base of the Coal-measures, for the First Grit apparently dies out at Mow Cop; so that for a short distance south of this point this base has been drawn at the top of the Third Grit.

The general and distinctive characters and disposition of the different bands of grit will now be described.

The Fifth Grit.—This grit in the north-east of the district caps a small hill north-east of Heaton, where it dips south-east near the south end of a syncline with northerly trend. About fifteen feet of lavender-coloured grit can be seen in a small quarry. It is very hard, massive, and rather coarse-grained, with an occasional small pebble, in the lower part, but flaggy and micaceous above, with intercalated beds of purple micaceous shale. The above description applies equally to other sections of this grit in the neighbourhood. It is seen again south of Heaton, in the brook and near the north side of it, for some distance, striking west-north-west with a small south-westerly dip. Here it evidently belongs to the syncline into which the beds are thrown east of the Rudyard Reservoir. The grit appears at intervals in stream-sections as far south as the point where a fault brings up the Trias.

At and near Rushton Spencer two patches of "Permian sandstone" were represented on the old map as lying unconformably on the shale below. Though no section exposes the actual junction of this grit with the shales which underlie it, and its relationship to higher beds is not seen, its strict concordance with the strike of the Carboniferous shales as determined by the folding, clearly shows its conformity with them. The northerly diminution of the shallow synclines on either side of the Rudyard Reservoir suggests that a bed of no great thickness, such as this grit, might remain at or close to the surface over a considerable area, and this seems actually to be the case.

Near the inn at Rushton James, a red and purple grit with soft purple micaceous beds and white blotches, due to removal of iron by weathering, lies on the strike of the Rushton Spencer grit, and undoubtedly forms part of the same outcrop. It was formerly mapped as Bunter. Though somewhat similar in colour to the lavender sandstones of the Keele beds of the

Coal-measures (Permian of the old survey) it is a sharper harder, and more quartzose grit, weathering to red sand and loam; while the highly felspathic Keele sandstones usually produce a stiff crimson marl. But the grit of Rushton exactly tallies in appearance with the Fifth Grit further east, and also with the Fourth Grit under Cloud Hill. It can safely be said that it is a Millstone Grit below the Third Grit, most probably from its position the Fifth. Mr. Barrow considers that it closely resembles a common aspect of the Stanley Grit, which is probably the Fifth.

A similar grit appears south-west of Horton, on the east side of the Lask Edge anticline. It also is probably the Fifth Grit of this district, and like the one at Rushton it may very well be the Stanley Grit. West of the same anticline at Crowborough, a soft, crumbly, white, red, and purple grit, with occasional small pebbles, may from its position represent the variable Stanley Grit, and would seem to be the Fifth, though not like its appearance further north. The same grit appears again south-south-east of the church at Biddulph Moor, but there is no indication of the Fifth Grit further west. A considerable thickness of dark shales, not completely seen, separates this grit from the Fourth Grit above.

The Fourth Grit.—The Fourth Grit affords the most striking example of rapid diminution of thickness. In the syncline east of the Rudyard Reservoir its outcrop rises into bold features, which suggest a thickness as great as or greater than that of the Third Grit, which it closely resembles lithologically. In the northern part of this shallow syncline the overlying shale seems to have been entirely removed, and an outcrop of grit three-quarters of a mile in width is masked only by Drift. The rock is a current-bedded coarse-grained, red, purple, and white massive grit with pink felspar and seams of pebbles. On the west side of the reservoir its features, below those of the Third Grit, are still large, but the bed has probably decreased in thickness. At Horton it must have diminished considerably. It is here a soft, porous, red grit, with bands of purple shale in its upper part. It reappears below the Third Grit in the flank of Cloud Hill as a thinner lavender-coloured grit, with purple shale and flaggy beds, similar in appearance to the Fifth Grit of Heaton and Rushton. From the east flank of the Cloud southward it seems to split into several thin beds of red, purple, and white grit, which can be traced as far south as Wren Clough, west of Rushton. On the east side of the Biddulph Valley, according to Green, it runs as far south as the brook which flows through Spring Coppice, north of Biddulph Moor.* In this brook, some distance below the Third Grit, several thin beds of yellow, red, and purplish fine-grained grit, often flaggy, crop out close together.

* *Mem. Geol. Surv.*, Geology of the Country round Stockport, Macclesfield, Congleton, and Leek, p. 69.

The Fourth Grit makes no further appearance to the south. From the west side of Cloud Hill it can be traced below the Third Grit as far south as Timbersbrook, where excavations in connexion with the dam of the mill-pond lately exposed some eight feet of red and purple grit below the Third.

Grey, black, and purplish shales intervene between this grit and the Third. At Biddulph Moor they may be upwards of 150 feet in thickness. There is room for nearly as much shale at Wren Clough, but probably not at Timbersbrook.

The Third Grit.—This, the most persistent bed in the district, makes a strong feature in the Rudyard syncline, and together with the First Grit forms the hilly margin of the Biddulph Valley. Though it doubtless diminishes in thickness southward and westward, it has not died out before plunging southward under the Coal-measures at Mow Cop.* This general diminution of thickness is probably not uniform—a remark which applies equally to the other thick grits—as the bed doubtless swells or contracts with the growth or dying out of the lenticles which compose it.

In lithological character the Third Grit is variable, but can be distinguished usually from the First Grit by its more pebbly nature. Sometimes it contains but few scattered pebbles, often thin pebbly seams, and occasionally small lenticles of conglomerate, the pebbles however being always small. The grit often contains a considerable amount of pink felspar, and sometimes, as at Mow Cop, veins of barytes filling joints. It is strongly current-bedded as a rule, though perhaps less so than the First Grit. Its colour, which is usually white with streaks and blotches of red and purple, varies from place to place. The grit, while generally a hard massive and compact rock, often contains beds of soft sand. Green noted a bed of very pure white clay, six feet thick with two or three inches of red hæmatite at the bottom, within the grit on Congleton Edge, near Brookhouses.†

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* The grit at Mow Cop was regarded by Green as the Rough Rock or First Grit (see *Mem. Geol. Surv.*, Geology of the country round Stockport Macclesfield, Congleton, and Leek, page 70). However, close to where the tramway passes under the hill is a gap, west-south-west of Mow House Farm, which indicates displacement by a fault. From the north to this gap the First Grit appears to diminish rapidly, till a short distance north of the gap it can only be traced with difficulty, while the lower grit continues as strongly as before. Only one grit, evidently the lower or Third, appears south of the gap. It is true that Farey speaks of the First Grit as capping Mow Cop (see "A List of about 700 Hills and Eminences in and near Derbyshire, with the *stratum* that occupies the top," J. Farey, *Phil. Mag.*, vol. xxxviii., p. 161 *et seq.*); but that author evidently adopted the more rational order of numbering the grits in ascending sequence (see J. Farey, "General view of the Agriculture and Minerals of Derbyshire," vol. 1, p. 129 (section p. 178 and p. 220), so that his First Grit is the lowest of the local series, in this district the one now called the Third.

† *Mem. Geol. Surv.*, Geology of the Country round Stockport, Macclesfield, Congleton, and Leek, p. 70.

As a physical feature the outcrop of this grit does not always behave in the same way, though it usually makes a strong escarpment. East of Wickenstones it forms a good escarpment, but no dip-slope, the ground from the top of the feature to the base of the First Grit being a level plain. Further north the escarpment forms a less conspicuous rise than the dip-slope, while round the north end of the valley both are equally well marked. On Congleton Edge the escarpment is strong, but the dip-slope is often a short and gentle incline.

The shales between the Third and First Grits seldom appear in section. In the stream-valley near Spring House, east of Biddulph, purple sandy shales and flags are seen just below the First Grit, but a stream flowing south-west from Cloud Hill to Timbersbrook affords the best section of the intermediate shales. Here, dark shales of considerable thickness with bands of ironstone-nodules and occasional thin beds of flaggy grit, sometimes contain fish-scales. Green gives the following section exposed in a newly opened road-cutting in the strata between the same grits, presumably on Congleton Edge, but he does not state the exact locality.

Character of Strata.	Thickness. Ft.	In
Rough Rock, coarse massive grit and conglomerate	–	–
White sandy clay, with a bed of sandstone at the bottom	3	0
Pink and white sandy clay, with beds of sandstone	13	0
Hard fine grit, in parts a conglomerate	10	0
Pink and white sandy shale, with beds of sandstone	14	0
Hard fine sandstone	5	0
Shale, sandy and pink in the upper part, dark and clayey lower down	57	0
Interval, with no section, most likely shale; Black shale; COAL, 2 ft. to 4 ft.; Underclay and shale (?), 4 ft. to 6 ft.	102	0
Third Grit, massive, not very coarse.		
	204	0

The First Grit.—This grit in the east has bent round further south in the Rudyard and Shaffalong syncline, and consequently does not enter the district here described; but in the west it runs round the Biddulph Valley, dying out southward on that side at Mow Cop. It is generally a coarse-grained, red, or white and red, current-bedded grit with felspar, sometimes pebbly, but on the whole less so than the Third Grit, besides being as a rule softer and more porous. Its outcrop, like that of the Third Grit, produces features of varying aspect. At Wickenstones and northward to Spring Wood, it makes an intermittent escarpment,

numerous gaps separating the ragged edges of bare grit, which are often undercut by weathering into overhanging cliffs. From Hurst Quarry, where the soft grit is worked for moulding sand, it makes no outcrop-feature, but has a strong dip-slope; while northward it runs to the north end of the valley in a series of ridges more conspicuous on the dip-slope than on the escarpment side. West of the valley where, in conjunction with the Third Grit, it forms the escarpment of Congleton Edge, its dip-slope is a strong one, often steep, while as a rule nothing but a slight break in the declivity of the ridge marks the outcrop of its base. From here south-westward it seems to diminish rapidly until at Mow Cop it can scarcely be traced upon the dip-slope of the Third Grit, after which it apparently dies out altogether.

CHAPTER IV.

CARBONIFEROUS ROCKS (*continued*).

COAL-MEASURES (General Account) by W. GIBSON.

Introduction.—In common with other English coal-mining districts the North Staffordshire Coalfield can lay no claim to picturesqueness, though some of the most lovely landscape of central England lies close at hand. The people of North Staffordshire are, however, justly proud of the compactness and completeness of the coal-measure succession, its richness in minerals, and the abundance and excellent preservation of the organic remains.

The coalfields might be taken in the order they would be met with on approaching them from the limestone region of Derbyshire—firstly, the trough of the Cheadle Coalfield; secondly, the shallow and narrow basin of Shaffalong, and the compact though small basin of Goldsitch Moss; thirdly, the remarkable coalfield of the Potteries, which, as it presents the type not only for N. Staffordshire but for each of the surrounding Midland coalfields, will be described first.

COALFIELD OF THE POTTERIES.

General Grouping of the Measures.—The First Grit, where it plunges, at a high angle, to the west from off the Endon-Werrington Anticline (p. 25), is succeeded conformably by the important division of the Coal-measures. In the area chiefly occupied by the Pottery towns the strata are arranged in a deep fold in the form of a triangle, of which the apex lies a little north of Biddulph, with the base, about ten miles in length, stretching from Apedale to Longton. West of this trough the lower portions of the Coal-measures rise up in a sharp anticline, evidently a southerly continuation of that at Astbury which there brings up the Carboniferous Limestone (p. 19). Including the sandstones and marls formerly placed in the Permian formation, the carboniferous rocks above the Millstone Grit attain the great thickness of over 7,000 feet. A two-fold grouping becomes clearly evident. The lower sub-division, exceeding 5,000 feet in thickness, includes the main seams of coal, the enclosing strata consisting of repeated alternations of sandstone, shale and fireclay of a nearly universal grey or black colour. It includes all the strata between the First Grit and Bassey Mine Coal. The upper sub-division, over 2,000 feet thick, lying above the Bassey Mine Coal, consists mainly of red sandstones and marls, in which grey rocks occupy a definite,

but quite subordinate, position. Workable seams of coal, associated with valuable bands of ironstones of the variety known as "Blackband," are confined to the lower portion of this group.

The lower sub-division has been usually divided into a middle and lower portion, an arbitrary line being drawn at the Ash Coal According to Mr. Kidston, the distribution of the plants favours such a classification; but the very fact that he recognises a feebly developed zone containing a mingling of Middle and Lower Coal-measure plants indicates the gradual passage of one group into the other, and this is fully supported by the stratigraphical evidence. Dr. Wheelton Hind, mainly from the study of the Lamellibranchs, favours no such sub-division, or, if one is to be made, that the line should be drawn at the Seven Feet Bambury Coal.

In former years marine fossils, more especially *Pterinopecten* (*Aviculopecten*) *papyraceus* and *Lingula mytiloides*, were regarded as a sure index of a low horizon in the Coal-measure sequence, but recent experience in this and other coalfields shows that these fossils have a widespread distribution high up in measures considered, on other evidence, to belong to the middle sub-division. On the whole, before making any attempt to subdivide the Coal-measures, it appears safer to wait for further evidence, and until the adjacent coalfields have been examined in the light of modern palæontological research and stratigraphical principles. Constant change and clashing of conflicting opinions will otherwise represent the nett result. It should also be recognised that of the 5,000 feet of strata forming the lower group, comparatively a small portion has been examined, though the Pottery Coalfield has probably been more carefully searched than any other area of a similar size.

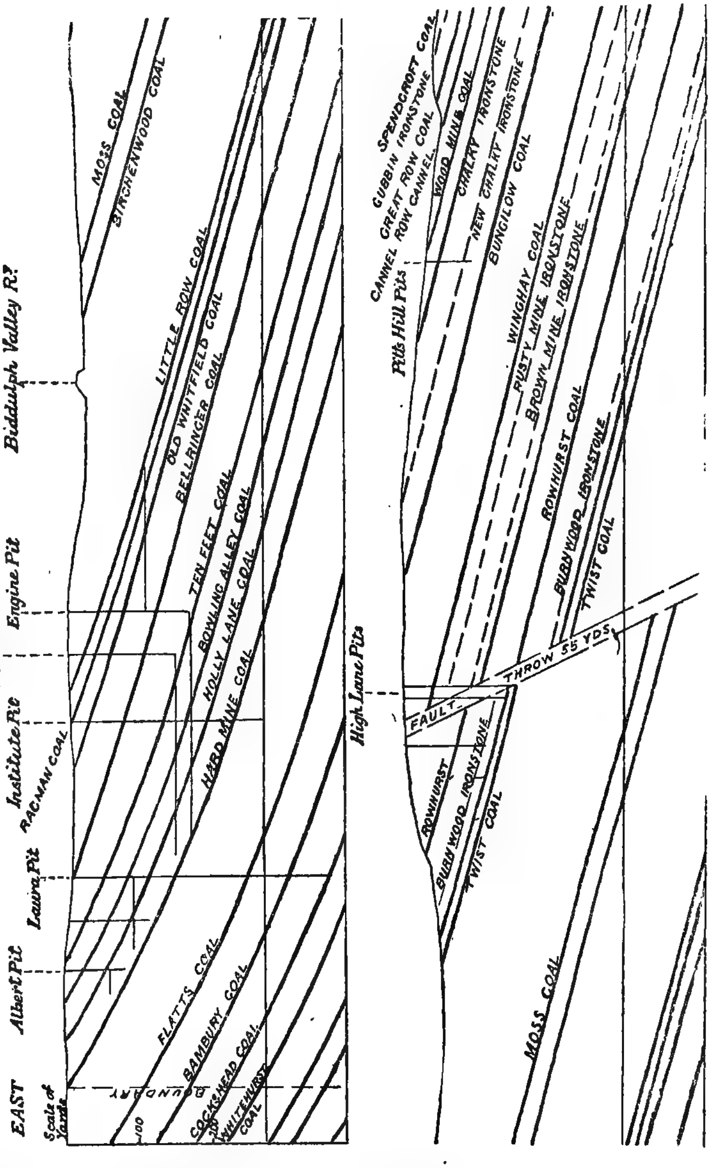
With the upper sub-division the grouping presents no difficulty, as the strata consist of distinct lithological types, with a characteristic fauna and flora; while the sequence can be studied in a multitude of natural and artificial sections scattered over nearly the whole breadth of the outcrop, and frequently, as in the large marl pits, extending continuously along lines several miles in length. The word upper is not used here in the sense it is employed in other coalfields; in fact the flora and certain field evidence lead one to suspect that these higher strata, including the so-called "Permian," by no means represent the latest deposits of the Coal-measure period. It may however be confidently stated that the sequence is identical with that met with above the coal-bearing strata of the Denbighshire, South Staffordshire, and Nottinghamshire coalfields.

In the following general account, the two main rock groups will be separately described in ascending sequence.

1. THE GREY OR CHIEF COAL-BEARING SERIES.

Arrangement.—The outcrop of this sub-division presents the form of a double fork. The angle between the two southern arms is occupied by the upper sub division, lying in the

.—SECTION SHEWING THE RELATIVE POSITION OF THE CHIEF SEAMS OF COAL AND IRONSTONE. (After C. HOMER.)*



* Trans. N. Staff. Inst. Min. Eng., Vol. II., 1875.

centre of the syncline between Golden Hill and the southern margin of the coalfield. The eastern branch forms a portion of the main syncline; while the western branch composes the

core of the conspicuous anticline extending from Madeley Heath to Kidsgrove and beyond. After uniting their outcrops at Golden Hill, they again diverge: the western arm continuing northward past Hall o' Lea Colliery in the direction of Mow

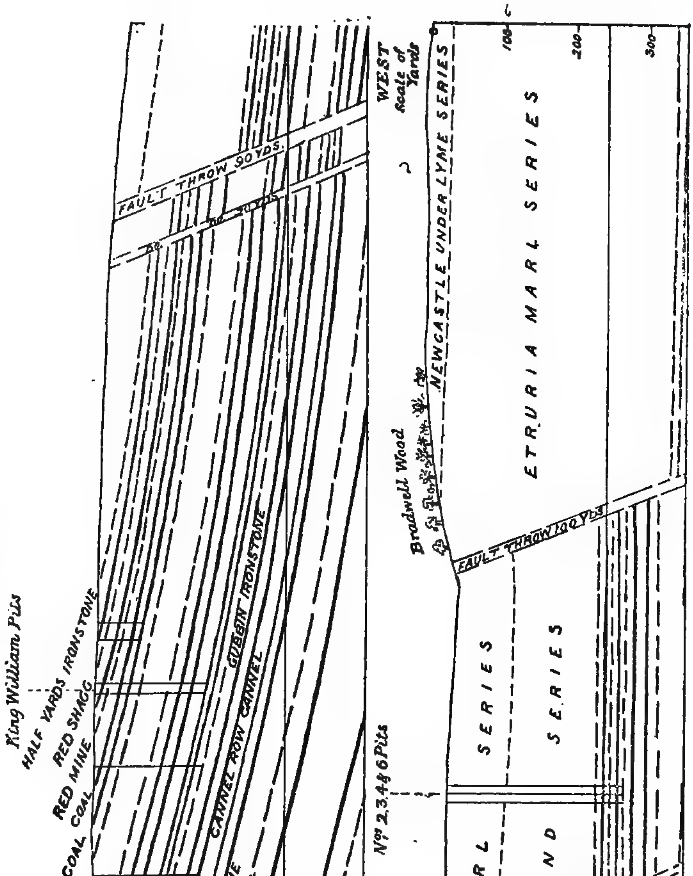


FIG. 6—Continued

Cop; the eastern branch extending nearly due north and constituting the Biddulph Trough; the ground dividing the two separate outcrops being now occupied by the Millstone Grit

ridge of Mow Cop. The strata are highly inclined—from 30 to nearly 90 degrees—around the edges of the northern part of the syncline, but the angles diminish gradually towards the centre of the trough, and generally on the south (Fig. 6 p. 40). In the anticlinal region the strata slope at high angles off the saddle, but rapidly flatten out both on the eastern and western side, and on the summit of the dome. The inclination remains greatest on the western flanks, where it frequently becomes vertical or even passes it, the coal seams and associated rocks being known in one case (Podmore Hall Colliery) to be slightly folded on themselves. These highly-inclined seams are, indeed, the chief feature in this western area, where they are known as "rearers," and necessitate a special mode of working, said to be a local art.

Distribution.—The distribution of the sub-division just described has arisen from the character of the folding, but faulting plays a no less prominent part. Thus on the west, the coalfield abruptly terminates against a belt of powerful disturbance, which we have named the "Western Boundary Faults" (p.), throwing down the measures over 2,000 feet. The presence of the upper group in the heart of the coalfield is due in part to folding, but largely also to the trough character of the Longton-Chatterley and the "Great Apedale" faults (p.), the latter at one spot possessing a throw of over 1,500 feet. Again, south of Longton, a fault of 250 yards downthrow south suddenly introduces the Upper Series. Besides these major fractures there are many smaller faults which, though not greatly interrupting the sequence, are a continual source of annoyance to the miner, constituting, in fact, one of the chief drawbacks to the coal-mining industry in the district.

Composition.—In composition the strata, from summit to base, consist of alternations of sandstone, shale, fireclay and coal-seam, the same order being repeated again and again, indicating, as has been pointed out for the coal-measures generally by Mr. Strahan,* a constant recurrence of similar conditions, the sandstones indicating an episode when sedimentation was at its maximum, the coal-seams a minimum period: when, if the growth of coal in situ be in some instances correct, sedimentation even ceased for a while. The frequent recurrence of marine organisms—from the summit of the First Grit to as high as the Bay Coal, 600 to 800 feet below the summit of the chief coal-bearing group—shows at once that the sea throughout the period lay at no great distance, and was ever ready to invade the area, during a time when the downward movement was more than usually active, or when a hitherto existing barrier was swept away. The numerous "mussel bands," made up largely of *Carbonicola* (*Anthracosia*), usually taken to be an estuarine or fresh-water genus, denote, on the other hand, the proximity of land.

* On the Passage of a Seam of Coal into a Seam of Dolomite. *Quart. Journ. Geol. Soc.*, vol. lvii. (1901), p. 302.

The unequal rate of sedimentation and its changeable character is still more forcibly illustrated by the varying thickness of the strata between known horizons. Thus the vertical thickness which separates the Bassey Mine Coal from the Winpenny Coal (between 1,000 and 1,200 feet above the First Grit) amounts to over 3,300 feet in the central part of the coalfield, and to 4,000 feet in the northern area, but has diminished to a little under 2,000 feet in the western anticlinal region. The thickening in the northerly direction chiefly takes place between the Winpenny and Yard coals, while the westerly attenuation is general. Movement at the time of deposition and concomitant change in the rate of transportation seem the best explanation of this phenomenon.

Having given in broad outline the distribution, arrangement, chief characters and mode of formation of the strata as a whole, we will now pass to the general economic aspect of the inquiry.

The great number of seams of coal distributed at intervals throughout the strata, but in greatest abundance above the Winpenny Coal, strikes everyone who has studied this remarkable coalfield. They number over forty-two seams, representing an aggregate of 130 feet of coal. Steam, manufacturing, house and gas coals are represented, and, what is of considerable importance to the district, the higher seams yield large quantities of cheap fuel suitable for use in the pottery kilns Beside coal there are numerous beds of clayband ironstone, though these are not so extensively mined as in the past. The Chalky Mine and Burnwood ironstones, ranked, however, by some as semi-black bands, remain in considerable request. Further, the highest rocks consist of pale marls, of great value in brick-making and fashioning the "saggars" in which the potter places his wares in the kiln.

Seams of Coal and Ironstone.—The order of the coal-seams and ironstones in descending sequence is given in the following table.*

SYNCLINAL AREA.	ANTICLINAL AREA.
Bassey Mine.	Pottery Bassey Mine.
Little Row.	
Peacock.	Peacock.
Spencroft.	Spencroft.
Gubbin Ironstone.	
Great Row.	Great Row.
Cannel Row.	Cannel Row, Little Mine or Little Row.
	Gubbin Ironstone.
Wood Mine Ironstone.	
	Blue Flats Ironstone.
Pennystone Ironstone.	
	Sheath Mine Ironstone.
Deep Mine Ironstone and Coal.	Deep Mine (Blackstone) Ironstone and Coal.

* In the construction of this table the chart by Messrs. Hind & Stobbs has proved of much service. Hind, W., and Stobbs, J. T. Chart of Fossil Shells found in connection with the seams of Coal and Ironstone. *Hanley*, 1903.

Synclinal Area.	Anticlinal Area.	
	Rusty Mine Ironstone.	
Chalky Mine Ironstone and Coal.	Chalky Mine Ironstone and Coal.	
New Mine (New Chalky) Ironstone.		
Hanbury Ironstone.	New Mine Ironstone.	
Rag Mine or New Mine Ironstone.		
Bay or Lady.		
Knowles or Winghay.	Winghay.	
Priorsfield Bass.	Brown Mine Ironstone.	
Knowles Ironstone.	Gold Mine Ironstone.	
Ash or Rowhurst.	Rowhurst.	
Binghay or Bingay.		
Burnwood (Little Mine) Coal and Ironstone.		
Gin Mine, Twist or Pottery.	Twist.	
Doctors Mine.		
Bee Coal.		
Birchenwood or Granville.	Birchenwood.	
	Little Row.	
Moss or Mossfield.	Single Four Feet or Easling.	
	Yard.	
Moss Cannel.	Single Two Feet.	
	Rider.	
	Single Five Feet or Four Feet.	
Yard.		
Ragman, or Hams.	Ragman.	close together on W. side.
Birches, Old Whitfield, Rough Seven Feet, or Seven Feet.	Rough Seven Feet.	
	Five Feet or Hams.	
	Smithy.	
Bellringer or Stony Eight Feet	Stony Eight Feet or Ten Feet Rider.	
Ten Feet.	Ten Feet.	
Bowling Alley, Magpie or Top Two Row.	Top Two Row, Tatchen-end, Little Row or Two Row.	
Holly Lane or Under Two Row.	Holly Lane, Bottom Two Row or Two Row.	
	Muck.	
Hard Mine, Sparrow Butts, Bowling Alley (Biddulph).	Bowling Alley.	
Muck Row.		
New Mine, Stinkers or Stinking.	Johnny Galley.	
Bright (Falls Colliery).		
Ragman (Falls Colliery).	3 Small Coals.	
Little Mine or Ironstone.		
Seven Feet Bambury, Bambury, Froggery or Frogrow.	Seven Feet Bambury or Seven Feet Nabbs.	
Cockshead, Eight Feet Bambury or Newpool.	Eight Feet Bambury or Eight Feet Nabbs.	
Limekiln, Sudden or Whitehurst.		
Bullhurst.	Bullhurst.	
Winpenny.	Winpenny.	
Brick Kiln.		
Bee Coal.		
Silver Mine.	Silver Mine.	
Cannel Row.		
Crabtree or Four Feet.		
Little Row or Two Feet.		

Character of Coal Seams.—One of the salient features in the distribution of the seams of coal, is the nearly total exclusion of gas and coking coals from the eastern area, the change from the one class to the other being stated to take place abruptly in the neighbourhood of the Oldcote Fault (p. 163). Above the Ash Coal no coking coals are met with. The following table, which must not be taken to show the correlation of seams, gives this difference in character for the chief seams in the lower part of the group:—

TABLE SHOWING CHARACTER OF CHIEF SEAMS.

Eastern Area.

Name of Seam.	Character.
Moss Coal -	House.
Little Row Coal	"
Yard Coal - -	House and Potters.
Old Whitfield Coal	Manufacturing.
Stony Eight Feet Coal	Blast Furnace.
Ten Feet Coal - -	Manufacturing.
Bowling Alley Coal -	"
Holly Lane Coal	House.
Hard Mine Coal	Steam and Blast Furnace.
Seven Feet Bambury Coal	House.
Cockshead Coal	"
Bullhurst Coal -	"

Western Area.

Name of Seam.	Character.
Four Feet Coal -	House
Single Five Feet Coal -	"
Ragman Coal	Steam.
Seven Feet Coal	House.
Hams Coal -	Steam.
Ten Feet Coal -	House and Gas,
Seven Feet Bambury Coal	" "
Eight Feet Bambury Coal	" "
Bullhurst Coal	" "

Special Features of Interest.—The detailed account of the series will be found in the succeeding chapter, but there remain certain variations in the characters of the measures, distribution of the fossils and special bands of rock to which attention may now be drawn.

The prevalent colour of the lower series, as previously stated, is grey, but red beds, as we shall now see are not wanting. The lowest horizon, consisting of red shales with bands of red grit, occurs in a position above the thin coals towards the base of the series, but are rarely seen except in some excavations on Wetley Moor, and in the streams running into the Trent off the moorland—notably the one near Ash Hall.

The next group of red sandstones and shales, from 40 to 50 feet thick, but apparently of more local occurrence, lies between the horizon of the Yard and Moss coals, and might readily be mistaken for the red beds of the upper series. This has actually been done with some red sandstones on the western margin of the coalfield, but which, in reality, occupy a position towards the summit of the lower series.

The red colour is always fitful, and may in part be due to subsequent staining or oxidation of the iron, but some of it is no doubt original. Whatever the origin, the low position in the Coal-measure sequence, of red measures very similar to those forming the bulk of the upper series, should caution the geologist about assigning them a definite position in borings through the red rocks of the Trias, as has sometimes been done. This can only be satisfactorily determined by palæontological evidence. Of the value of such evidence the district affords a good example, consisting in the fact that the red beds of the lower series are always associated with strata containing large forms of *Carbonicola* (*Anthracosia*), and *Anthracomya*, which are totally absent in any of the beds of the upper series.*

Another feature of general interest to the student is the presence of bands containing marine organisms occurring on nine distinct horizons throughout the inferior coal-bearing group. Allusion to their occurrence has been previously mentioned in discussing the conditions under which the strata were deposited, but of late years the subject has gained considerable importance from the aid these marine bands afford in the difficult task of correlating the seams over the district, and also from the fact that the re-survey of the Derbyshire and Nottinghamshire coalfield demonstrates their occurrence on several horizons throughout the coal-measures of those regions.

The presence of marine bands in the Gannister Series of Lancashire, and the so-called Lower Coal-measures of other areas, since they were considered to be rare, or altogether absent

* In the Radstock-Farington Series of Somersetshire, judged to be of Upper Coal-measure age on plant evidence, *Carbonicola aquilina* is stated to occur; while *Anthracomya Wardi* is associated with the Red Coal-measures of Fifeshire, which, on plant evidence, are considered to belong to the Middle Coal-measures.

higher up in the sequence, has been urged as a basis of classification;* but their rarity on these higher horizons has now been proved to be erroneous, and if such marine bands are to be retained as a means of correlation the summit of the sub-division of the so-called Lower Coal-measures must be drawn at a much higher horizon than hitherto, and would in fact, include nearly the whole of the chief coal-bearing strata in North Staffordshire.

Fossils of marine types were first observed in the roof of the Two Feet and Four Feet coals, situated a few yards above the "First" Grit †; afterwards, Mr. Ward found them at much higher horizons in the Longton area, up to as high as the grey shale overlying the Bay Coal (p. 50), about 600 feet below the Bassey Mine ‡. Recently, Mr. Stobbs has traced over wide areas many of the bands discovered by Mr. Ward at Longton, in addition to bringing others to light §.

The bands with marine types lie in the midst of strata containing numerous remains of *Carbonicola* (*Anthracosia*), but the general statement by Mr. Ward still holds good. "After a careful search I have failed to discover in the North Staffordshire coalfields, mollusca of a fresh-water facies in direct association with those of marine types. In every instance where the two have approached each other the line of demarcation has been clear and distinct."

We will now give the horizons and the fossil contents of these marine bands, commencing with the lowest.

FOSSILS FROM THE ROOFS OF THE TWO FEET COAL AND FOUR FEET COAL.

Lingula mytiloides.
Discina nitida.
Pterinopecten (Aviculopecten) papyraceus.
Schizodus sp.
Gastrioceras Listeri.
Orthoceras, sp.

These fossils have hitherto been regarded as sufficient evidence to warrant the identification of the strata with the Gannister Beds of Lancashire, the lower part of the

* *Hull, E.*—On the Upper Limit of the essentially Marine Beds of the British Isles, and adjoining Continental districts, with suggestions for a fresh Classification of the Carboniferous Series." *Quart. Journ. Geol. Soc.*, vol. xxxiii., p. 648. [1877.]

† Iron Ores of Great Britain, Part. iv. *Mem. Geol. Survey*, p. 264. [1861.]

‡ The Geological Features of the North Staffordshire Coalfields. *Transactions of the North Staffordshire Institute of Mining and Mechanical Engineers*, vol. x., 1890.

§ Recent Work in the Correlation of the Measures of the Pottery Coal-field of North Staffordshire, with suggestions for further development. *Transactions of the Institution of Mining Engineers*, Vol. xxii., p. 229.

Coal-measures of Shropshire, and the Rosser Vein Series in South Wales—but we shall meet with them again higher in the series. It is interesting to note that at distinct horizons on Wetley Moor, and in the stream section near Ash Hall, shales and ironstones, with numerous *Carbonicola* have been met with; for while some of the marine types in the above list are found in the Millstone Grit, and the beds below, *Carbonicola*, so far, has not been found in Staffordshire in association with these inferior strata, though in other regions (Hebden Bridge and S. Wales) it is not uncommon in beds, regarded as of Millstone Grit age.

Next in ascending the sequence *Pterinopecten* (*Aviculopecten*) *papyraceus* has been noted in shales between the Winpenny and Four Feet coals at Knypersley Reservoir*, but we have failed to find this horizon. Marine fossils are also stated to occur above the Winpenny Coal and Bullhurst Coal.†

The next horizon, that above the Seven Feet Bambury Seam, is of particular interest.‡

SECTION GIVING THE POSITION OF THE MARINE BED ABOVE THE SEVEN FEET BAMBURY SEAM AT LEYCETT.

(To be corrected for an inclination of 30 degrees).

	FT.	INS.
Shales with nodules (Marine Band) -	15	0
RIDER COAL (No. 3)	0	9
Shale- ·	6	6
RIDER COAL (No. 2)	1	0
Shale -	1	0
RIDER COAL (No. 1)	2	0
Shale. - - ·	10	0
BAMBURY SEVEN FEET COAL	5	6

The shale forming the roof of No. 3 Rider Coal is irregularly laminated and contains a layer of nodules, yielding fossils in good preservation.

In nodules :—	Pterinopecten papyraceus, *Sow.*
	Glyphioceras? paucilobum, *Phill.* sp.
	Carbonia. sp.
	Dithyrocaris testudineus? *Scouler*
In roof shale —	Pterinopecten papyraceus, *Sow.*
	Posidoniella lævis, *Brown*
	Rhizodopsis sauroides *Mill* (scale).

Up to the present time this band has only been found on the western side of the coalfield. It will be observed that some of the fossils are of the same species as those met with in the beds below the Millstone Grit. In one band of dark shale *Lingula mytiloides* was found side by side with *Carbonicola* a most exceptional association.

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* Iron Ores of Great Britain, part iv. (op. cit.), p. 264.

† *Wheelton Hind*—Palæontographical Society.

‡ *J. T. Stobbs*, "On the Discovery of a new Marine Bed in the Coal-measures at Leycett, North Staffordshire." *Trans. North Staff. Field Club.* Vol. xxxv., 1901.

Over 1,000 feet of strata in which no marine bands have yet been discovered succeed this horizon. We then come upon a bed which has been traced at intervals from Longton on the south to Sneyd Colliery, a distance of five miles, and has also been detected on the western side of the coalfield. This bed occurs a few feet below the Moss Coal, varying its position very little, as shewn in the following sections, commencing on the south.*

MARINE BED BELOW THE MOSS COAL AT THE FLORENCE COLLIERY, LONGTON.

(From Mr. E. P. Turner.)

	FT.	IN.
MOSS COAL SEAM	5	6
Measures - . . -	13	9
Dark shale (*Lingula mytiloides*)	2	0
COAL	2	5

The same bed was found by Mr. W. Plant at Berry Hill Colliery, in the following position :—

MARINE BED BELOW THE MOSS COAL AT BERRY HILL COLLIERY.

	FT.	IN.
MOSS COAL SEAM.		
Measures - . -	18	0
Dark shale (*Lingula mytiloides*)	3	0
COAL - - .	2	0

Further north in the workings of the Sneyd Colliery, where it was first discovered by Mr. Stobbs, the position of the band is as follows :—

MARINE BAND BELOW THE MOSS COAL AT THE SNEYD COLLIERY.

	FT.	IN.
MOSS COAL SEAM -	4	10
Measures - - -	20	3
Dark shale (*Myalina peralata*?) about	0	2
Measures, about - -	10	0
Black fissile shale (*Lingula mytiloides*) -	1	1
CANNEL COAL SEAM (MOSS CANNEL) - -	3	10

Lingula has also been found by Mr. W. G. Salt in proximity to the Four Feet Seam at the Silverdale Colliery.

During the sinking of the Longton Hall Colliery Mr. Ward also found *Lingula mytiloides* in dark shale lying on the spoil bank, and the horizon was said to be 108 feet above the Moss coal. It is doubtful if this is another horizon, or if the position was incorrectly determined. Mr. Ward has also obtained marine fossils from a somewhat doubtful horizon at Weston Sprink, though the available data indicate a position somewhere between the Moss and Yard coals. The marine fossils include *Pterinopecten (Aviculopecten) papyraceus, Discina nitida Pleuronautilus* sp. In addition to teeth of *Megalichthys Hibberti, Diplodus gibbosus*, scales of *Cœlacanthus elegans*; specimens of *Carbonia rankiniana, Myalina*, and the minute shell *Scaldia minuta*. The character of the beds will be found on (p. 66).

* *J. T. Stobbs. Trans. Inst. Min. Eng.* Vol. xxii, 1902.

The next horizon has been met with at widely distant localities at a distance of about 500 feet above the Moss Coal. The richness and variety of the fauna will be seen from the list (p. 320).

We now come to the highest horizon at which marine organisms have been shown to occur. These are met with in shale overlying the Bay or Lady Coal about 600 feet above the last-mentioned horizon. This was first discovered at Longton by Mr. Ward and subsequently by Mr. Stobbs at the Chell Colliery.

MARINE BED ABOVE THE LADY COAL AT CHELL COLLIERY. *

	FT.	IN.
Marine bed, light grey shale	0	2
Black shale, splitting readily	1	3
LADY COAL - - - - -	2	4
Fireclay, with fragments of Stigmaria		

The following fossils were obtained :—*Discina nitida, Lingula mytiloides Lingula squamiformis ?* Entomostraca, Fish-scales etc.

The coalfield presents yet another feature of special interest. This is the presence of at least one band of limestone with *Spirorbis* occurring at an horizon far below the Bassey Mine Coal. Its presence at a low horizon shows that in the absence of other data, such bands cannot be relied upon as indicative of a high position in the Coal-measure sequence. The band in question occurs just above the Bowling Alley Coal (p. 64), and has been traced by Mr. Stobbs almost over the entire district, both on the eastern and western sides of the coalfield. The bands are thin, seldom exceeding an inch or two in thickness, but the fossil is frequently met with in great abundance, *Spirorbis helicteres* being the commonest species. By means of this bed Mr. Stobbs has been enabled to show that the Bowling Alley Seam of the Potteries is the Magpie Seam of Biddulph, the Tatchin-end or Top Two Row Seam of Silverdale, and the Top Two Row Seam of Kidsgrove.† The character of the bed and its position with respect to the Bowling Alley Coal will be gathered from the sections (pp. 64-65).

THE RED AND GREY SERIES.

Characteristics. — The Coal-measures previously described consist of repeated alternations of sandstone, shale, fireclay, and seams of coal. Whatever may have been the conditions under which these different kinds of strata were deposited, geologically speaking, each phase was of brief duration, but of frequent recurrence. In this way the difficulty experienced in subdividing the coal-bearing strata in this as in other coalfields arises.

With the strata succeeding the Bassey Mine Coal the case is wholly different. Instead of consisting of alternations of grey sandstone, grey and black shales and seams of coal, the rocks with which we have now to deal fall naturally into four sub-groups, each

* (From a paper by Mr. J. T. Stobbs) *op. cit.*
† *Trans. Inst. Min. Eng.*, vol. xxii., p. (1902), p. 229.

of which possesses a definite lithological character, recognisable in the field and readily traced throughout the district.

These will be best understood from the following table :

TABLE SHOWING THE SUBDIVISIONS OF THE HIGHER COAL-MEASURES IN NORTH STAFFORDSHIRE.

Name of Subdivision.	*Characters.*	*Chief Organic Contents.*	*Thickness.*
KEELE GROUP.	Red and purple sandstones and marls. Occasional seams of coal. Thin black and grey limestones and subordinate bands of grey sandstone and shale. Base, entomostracan shale.	*Neuropteris Scheuchzeri*, *Pecopteris*, *P. arborescens* *Miltoni*, *Lepidodendron*, *Calamites undulata* *C. Cisti*, *C. Suckowii*, *Sphenophyllum*, *Cordaites*. *Spirorbis*, *Carbonia wardiana*, *C. pungens*, *C. scalpellus*, *C. rankiniana*, *Elonichthys*, *Diplodus gibbosus*.	Over 700 feet at Keele Park. Summit nowhere visible.
NEWCASTLE-UNDER-LYME GROUP.	Grey sandstones and shales with four thin seams of coal. Base, entomostracan limestone.	*Alethopteris aquilina*, *A. lonchitica*, *Calamocladus equisetiformis*, *Lepidodendron Sternbergi*, *L. variabilis*, *Mariopteris muricata*, *Neuropteris ovata*, *N. gigantea*, *Pecopteris arborescens*, *P. Miltoni*, *Stigmaria ficoides*, *Calamites approximata*, *Lepidostrobus variabilis*, *Sigillaria Brardi*, *Rhabdocarpus sulcatus*. *Spirorbis*, *Carbonia wardiana*, *Anthracomya calcifera*.	300-350 feet.
ETRURIA MARL GROUP.	Chiefly mottled red and purple marls and clays. Thin bands of green grit very characteristic. Limestone-bands near the summit and base. Lenticular mass of grey sandstone overlying a laminated ironstone, and thin coal 150 feet above the base (Chesterton only). Base, often a greenish, fine-grained sandstone.	Plant-remains undetermined. *Spirorbis*, *Carbonia*, *Anthracomya Phillipsi*.	800 to 1100 feet.
BLACK-BAND GROUP.	Grey sandstones, marls, and clays. Some lenticular bands of grey grit and slightly-mottled marls. Numerous thin seams of coal and Black-Band ironstones. Thin bands of limestone throughout the series, one of which is constant at 36 to 40 feet above the base. Base, Bassey Mine Coal.	*Calamites varians*, *C. Suckowi*, *Mariopteris muricata*, *Triletes*, *etc.* *Spirorbis*, *Carbonia*, *Anthracomya Phillipsi*, *Carbonicola (Anthracosia) Vinti*, *Megalichthys Hibberti*. *Cœlacanthus lepturus*, *Diplodus gibbosus*, *Ctenodus cristatus*.	300 to 450 feet.

For the plants see R. Kidston, *Trans. Roy. Soc. Edin.*, vol. xxxvi. (1892). For the other fossils, see J. Ward, *Trans. North Staffs. Inst. Min. and Mech. Eng.*, vol. x. (1890), and *Proc. North Staffs. Field Club*, vol. xxxiv. (1900), pp. 87-92 ; Wheelton Hind, *Monogr. Pal. Soc.*, vol. xlix. (1895), and *Quart. Journ. Geol. Soc.*, vol. lv. (1899), pp. 365-68.

Black-Band Group.—The character of these measures at various points in the district will be seen from a reference to the Sections, Nos. 38–50, Appendix No. III.

The group has been extensively excavated owing to the fact that the marls furnish the coarse materials used in the pottery trade for " saggars " and " stilts " and also for brickmaking, drain pipes, etc.

With much resemblance to the underlying measures, the group is characterised by the presence of Blackband ironstones and numerous persistent thin bands of lime stone, containing *Spirorbis* and Entomostraca ; by the presence ot many plants of species rare or absent in the beds below ; by the absence of large forms of *Carbonicola* and *Anthracomya ;* by the countless numbers of the thin valved mollusc *Anthracomya Phillipsi,* which frequently constitutes a considerable mass of the ironstones, and certainly forms a true " life zone."

We have shown that there is no break in the sequence from the Millstone Grit upwards to the Peacock and Little Row coals. In studying the relationship of the beds above the Bassey Mine Coal with those below, no trace of a palæontological or stratigraphical break can be detected. Thus the Bassey Mine Coal always overlies the Little Row Coal at about the same distance, while the identity of the character of the rocks above and below the Bassey Mine will be gathered from the sections given in the appendix. Further proof of this close relationship exists in the simultaneous gradual increase or decrease in thickness as the two groups are traced from south to north on the one hand, or from east to west on the other. Thus the Black Band Group at Shelton is 150 yards thick ; while at Apedale, four miles to the west, the thickness is only 90 yards ; and at Longton about 110 yards. Faults and folds also equally affect the two groups.

Etruria Marl Group.—At several horizons, notably a few feet below the Red Mine Coal and some distance above the Gutter Coal, the grey measures of the Black Band Group contain beds of red or mottled red marl from 10 to 15 feet thick ; while throughout the sub-division there is constantly a slight tendency to red mottling. This red colour and red mottling becomes the predominant characteristic of the great thickness of the overlying marls which, from their being very clearly exhibited in the marl pits at Etruria, we have termed the Etruria Marl Group.

This sub-division is essentially composed of red and mottled marls, several hundred feet thick, in which it is frequently impossible to distinguish any stratification. Towards the base, greenish-yellow grits are frequently developed, but not invariably. Grits of a kindred character, but seldom exceeding more than a few feet in thickness, recur at intervals, and are persistently and well developed near the summit ; where they occasionally (Etruria Marl pits) contain well-rounded quartz pebbles ranging in size from a pea to a pigeon's egg, rendering the rock not unlike the

coarser bands of the Millstone Grit. The finer varieties are found to be largely made up of igneous material; but, owing to decomposition, the evidence is not decisive as to whether the rock is a true ash, or derived from the waste of older lavas (see p. 131).

The junction of the Etruria Marls with the underlying beds is nowhere visible, but the close connexion of the two is shown by the presence of red marls in the inferior strata, as previously mentioned; by the occurrence at Chesterton of a laminated ironstone containing *Anthracomya Phillipsi* in association with several feet of grey measures; and by the presence of bands of *Spirobis* limestone, one about 80 feet below the summit, and another a few feet above the base.

Newcastle-under-Lyme Group.—The Etruria Marls graduate upwards (Sect. No. 59, Appendix III.) into grey sandstones and shales, and this so imperceptibly that were it not for the persistence of the thin beds of entomostracan limestones at the base of the grey series, it would be impossible to draw a dividing line. The junction of the basal limestone with the underlying marls is frequently irregular, indicating a small amount of erosion; but with such fine sediments as the Etruria Marls, the gentlest currents would easily wash them away, thus giving rise to irregularities. The composition of the Newcastle-under-Lyme Group varies little throughout the Pottery Coalfield, being made up of sandstones and marls containing four thin seams of coal. Plant remains are numerous, among which *Pecopteris arborescens* belongs, according to Mr. Kidston, to a high "zonal form."* *Anthracomya calcifera*, a small shell frequent in the shales associated with the basal limestone, in which it also occurs, has so far been found only high up in the Coal-measure sequence throughout the Midlands.

Keele Group.—In this sub-division we again meet with a great but undetermined thickness of red strata, consisting of sandstones and marls. These strata were regarded by Professor Hull as a portion of his "Salopian Permian," and to be referable to the Roth-liegende or Lower Permian of Germany. The great change made in this memoir in the correlation of these beds needs a full account of the palæontological and stratigraphical evidence on which it is based.

Throughout the Pottery Coalfield the Keele red sandstones and marls repose on the Newcastle-under-Lyme sub-division; which they do not overlap in the slightest degree, or with the least observable discordance. Professor Hull, on the other hand, states that from Audley to Blurton "the Permian red sandstones and marls rest with a slight discordance upon the Upper Coal-measures."† It is true that at Blurton Tileries, near Longton, the red sandstones of the Keele Group are in juxtaposition with

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* *Pecopteris Miltoni* is very abundant in association with the coal-seams.

† The Triassic and Permian Rocks of the Midland Counties of England, *Mem. Geol. Surv.*, 1869, p. 24.

the Etruria Marls and basal beds of the Newcastle-under-Lyme Group. This, in the absence of faulting, would imply a considerable unconformity; for at Dresden, 600 yards to the east, the Keele sandstones rest on the full thickness of Newcastle beds, but a fault, agreeing in direction with one proved underground to the east, has been shewn by actual trenching to have brought about the juxtaposition. The supposed unconformity near Audley has, however, a different explanation, the red sandstone, coloured as Permian on the old edition of the map, being in reality a Coal-measure sandstone developed near the horizon of either the Great Row Coal or Knowles Ironstone, that is some 1700 to 1800 feet below the base of the Keele Group.

Fossils are not abundant in the Keele beds, but sufficient plants have been collected to confirm the conclusion as to their age thus drawn from their stratigraphical position. Those given in the table (p. 51) and in the list of fossils (p. 337), all belong to Coal-measure forms, and excepting *Pecopteris arborescens* do not indicate a horizon even so high as the Radstock and Farington Series of the Somerset Coalfield; on the contrary, they are met with in the Lower Pennant-sandstone of South Wales. This somewhat low position in the Coal-measure sequence for the Keele beds is partly corroborated by the field evidence at Moddershall (p 126). At this locality we should be higher up in the Keele beds than elsewhere in the district, unless there is some faulting which cannot be detected at the surface. Further palæontological evidence of the Coal-measure age of the Keele sandstones is afforded by the bands of *Spirorbis* and entomostracan limestones met with at no less than three different horizons.

The sequence in North Staffordshire, from the Bassey Mine upwards, has been detected in other coalfields situated within the limits of Professor Hull's typical Salopian area, and also outside it. Thus, in the Denbighshire Coalfield, which has always been thought to be closely connected with the Pottery Coalfield, the grey Coal-measures are overlaid round Wrexham and Ruabon by red marls of the Etruria Marl type over 800 feet thick, and containing two thin beds of *Spirorbis* limestone and bands of green grits similar to those in North Staffordshire. These pass up into the grey Coedyrallt sandstones and shales with thin seams of coal, and a thin limestone at their base containing *Carbonia*, *Spirorbis*, and *Anthracomya calcifera*. The Coedyrallt rocks are in turn succeeded by red sandstones and marls identical with the Keele type. Around the southern margin of the South Staffordshire Coalfield we find the Upper Sulphur Coal Group, overlaid by some 300 feet of red coal-measure clays lithologically resembling the Etruria Marls, and also containing the characteristic bands of green (Espley) rocks. Above these come the grey Halesowen sandstones and shales over 500 feet thick, with thin coals, a band of *Spirorbis* limestone near the summit, and possibly

another at the base; these are overlaid by red sandstones and marls (Lower Permian of Prof. Hull and Mr. Wickham King) indistinguishable from the Keele Group, and in which Mr. Cantrill notes the occurrence of *Spirorbis* limestones.* In the Warwickshire Coalfield Mr. Fox-Strangways notes very much the same sequence. In Lancashire the description of the Upper Coal-measures of the Manchester Coalfield by Mr. Binnie leaves little doubt of the Ardwick Series belonging to a portion of the Staffordshire sequence above the Bassey Mine Coal.

Thus the Salopian Permian of Staffordshire, Denbighshire, Worcestershire, Warwickshire, and, in all probability, Lancashire, occurs as the highest group of a definite sequence everywhere overlying the higher beds of the true Coal-measures, but never discordant to them, and may, therefore, be regarded as belonging to the Carboniferous and not to the Permian Formation. This would receive the strongest confirmation if it could be shown that the Magnesian Limestone Series (Permian) of Nottinghamshire rests with a strong discordance on the Salopian Permian and its associated rocks. This has fortunately of late years been possible. A boring at Thurgarton showed that the basal bed of the Magnesian Limestone Series is a coarse breccia resting on red sandstone and marls of exactly the Keele type, and with the same fossils; these red beds passed down into grey sandstone and shales resembling the Newcastle-under-Lyme Group, and with the same plants; while these rocks rested on some 257 feet of red marls with green grits like the Etruria Marls. The boring did not satisfactorily prove the relation of these to the measures above the Top Hard Coal. This, however, was clearly shown in sinking the shafts of the Gedling Colliery. The Permian breccia at the base, about eight inches thick, here rests on about 100 feet of red marls and shales of the Etruria Marl type, and these on strata resembling the Black Band Group and containing its zonal fossil—*Anthracomya Phillipsi.* Thus between Thurgarton and Gedling, situated 7 miles apart, the basal beds of the Magnesian Limestone Series rest on horizons 400 feet apart. Elsewhere in the neighbourhood, the basal breccia reposes, often with an observed sharp discordance, as at Cinderhill, on strata much lower down in the Coal-measure sequence; but in all these cases the red and grey group of Staffordshire is absent. Thus the Salopian Permian on either side of the Pennine Chain conforms to the Coal-measures but is unconformably overlain on the eastern side by the Magnesian Limestone Series.

* Summary of Progress of the Geological Survey of the United Kingdom for 1901, p. 63. Also *Quart. Journ. Geol. Soc.*, vol. li., 1895.

CHAPTER V.

CARBONIFEROUS ROCKS—(*continued.*)

COAL-MEASURES (Detailed Description).

Introduction.—The eastern syncline and western anticline divide the Pottery Coalfield into two clearly defined portions, distinguished from each other by differences in the character, thickness, and inclination of the strata. These two regions will therefore be described separately, the account in each case commencing on the south.

THE SYNCLINAL REGION.

As we have seen the Coal-measures fall into two natural groups.

2. The Red and Grey Series.
1. The Grey or Chief Coal-bearing Series.

The highest of these occupies the central portions of the coalfield, coming to an apex at Golden Hill and rapidly expanding their outcrops southwards. The chief coal-bearing strata arrive at a point at Alder's Farm in the Biddulph Valley, where the synclinal arrangement becomes very evident. They then extend southward in a belt about four miles wide occupying the valley of the Trent until they disappear under the Triassic rocks south of Longton. Numerous collieries attest the richness of this portion of the sequence just as the barrenness of the higher group is indicated by their absence. These two groups will be taken separately in the order of their occurrence, commencing with the oldest.

THE GREY OR CHIEF COAL-BEARING SERIES.

As previously stated (p. 39) no subdivisions can be made on stratigraphical evidence of this great thickness of strata, nor are palæontologists agreed as to the horizons on which to draw the divisional lines. For purposes of description we shall take the rocks in sub-groups, using any lithological or mineralogical characters which happen, though often only in a very general way, to distinguish one portion of the sequence from another.

THE BASIN OF THE TRENT.

(By W. GIBSON.)

Measures between the First Grit and the Winpenny Coal. These occupy a broad belt of ground rising up steeply from the Trent to the Millstone Grit moorland. They are not clearly exhibited, but when seen they are generally highly inclined

though at such varying angles as baffles any attempt to calculate the thickness, which probably is never under 1,000 feet and exceeds 1,200 feet at Knypersley. Grey shales and lenticular bands of sandstone constitute the bulk of the measures, but fairly thick horizons of black shale occur near the base and summit. The sandstones are thinnest and least numerous in the south, but increase in importance northward, where they gradually assume the characters of the Millstone Grits. Very little can be gathered about the sequence and the character of the strata. The chief information relates to two seams of coal and their associated measures near or at the base of the group, where thin bands over the lowest containing marine fossils (*Goniatites, Lingula, Pterinopecten*) are interstratified with others containing *Carbonicola*. We think this poverty of information should be clearly understood, for it shows at once on what insufficient data these measures have been correlated with the Gannister Series of Lancashire and the Lower Coal-measures of other English coalfields. At present there is no evidence to show whether only the lowest two or three hundred feet are to be regarded as Lower Coal-measures or whether this subdivision is to include strata several hundred feet above the Winpenny Coal.

The Crabtree Coal and its associated rocks.—This group includes the lowest coal seams ever worked, but mining operations have ceased, owing partly to the inferior quality of the seams and partly to the inaccessible nature of the ground where they out-crop. In 1862, at the time of the original survey by Sir W. W. Smyth, coal was being raised on Wetley Moor from the two seams shown in the following section:—

SECTION OF THE CRABTREE MEASURES WETLEY MOOR.*

	FT.	IN.
FOUR FEET OR CRABTREE COAL	3	0
Marl or binds	45-60	0
Reddish rock	24	0
Black metals and rock bind	33	0
TWO-FEET COAL	1	8

The Four Feet Coal is stated to be of poor quality; the 20-inch coal very good for smiths' purposes. On entering the Pottery Coalfield to the west of Werrington, the first exposure is met with in the stream to the north of Ash Hall. An old shaft on the northern side of the stream, a few yards south of the by-lane leading on to Wetley Moor, reached the Crabtree Coal, but at what depth could not be ascertained. In the stream to the west of the by-road a purple grit, overlain by red shales, crops out, and is probably the "reddish rock" in the section on Wetley Moor. Nodules of red hæmatite, which recalls the Froghall Ironstone of the Churnet Valley, lie in the shales. The purple

* "Iron ores of Gt. Britain," part iv., *Mem. Geol. Survey* (1861), p. 264.

grit is underlain by dark shales containing a thin band of iron stone with *Carbonicola*. A few feet below comes a coal about a foot thick. Beneath this, black and grey micaceous flags complete the sequence, and probably represent the top beds of the First Grit.

Wetley Moor to the north is dotted over with old workings, from the shale heaps of which several fossils have been collected. The Crabtree Coal was obtained at a disused shaft situated near Launders Bank, while a little to the north the Two Feet Seam was apparently reached by an adit; for this passes through red shales and grit, evidently those mentioned in the section given above. The same red measures have been excavated in some disused clay pits (old sand pits on the six inch map.)

North of this point exposures are rare and very limited in extent. It is known, however, that the Millstone Grits between Woodhead Farm and Jack Hayes strikes east and west, or at right angles to their former trend. The Crabtree Coal and its associated rocks no doubt behave in a similar manner, but the position of the coal cannot be determined owing to the poverty of exposures. South of Kerry Hill a hard red grit has been quarried on the roadside, but its relation to the Crabtree measures cannot be determined.

Continuing northward the Crabtree Coal was reached in a shallow shaft situated by the stream flowing a few yards south of the road to Bagnall, at about 500 yards from its junction with the Leek Road. The strata here are highly inclined. At the eastern margin of the Milton nurseries a quarry has been opened in a pebbly grit separated by several feet of shale from the First Grit. The bed cannot be traced far to the north, but can be followed southward to Woodhead Farm.

Between Milton and Stockton Brook the slopes descending from the Grit ridges are mostly covered with Drift. This has been denuded away northward, when the solid rock again becomes visible for a short distance. The only certain evidence for the existence of the Crabtree measures is the occurrence of black papery shales in association with a thin coal seen in the old Brickworks near Ball Lane, and in an old level and shaft which obtained the coal in Bankend Wood, near High Lane Farm. The identification of this coal with the Crabtree becomes evident from the shale roof containing abundant *Goniatites*.

The dip slopes of Brown Edge yield few exposures, and no attempt has been made to obtain the Crabtree or Two Feet Coals. These measures are evidently cut through by the Trent in the deep and narrow gorge between the Gawton Stone and Knypersley Reservoir. The sequence is here somewhat changed, as will be gathered from the following section giving the approximate thickness:—

Crabtree Measures Knypersley Reservoir.

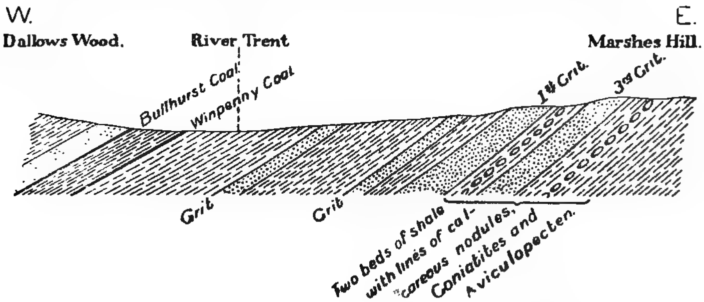
	Ft.	In.
First Grit.		
Black shales (eastern banks of reservoir)	† 30	0
Pebbly grit - -	30	0
Black shales (partly seen) with Fish scales.		
Coal - -		3
Shales (poorly shewn)		
Coal - -	1	0
Sandstone, light coloured	20	0
Red sandstone	30	0
White sandstone	15	0
Thin bedded red flags	3	0
Dark shale, about	100	0

It will be seen (p. 77) that further north the Crabtree Coal lies a few feet above a pebbly grit. If so, this seam should crop out close to the eastern margin of the Reservoir, and this would receive confirmation from a statement by Sir W. W. Smyth that the shales on the eastern bank contain *Aviculopecten papyraceus*, though the band with this fossil cannot be detected at the present day. Both the pebbly grit and the red and white sandstone make bold features on the surface for some distance north of the Warden Tower, becoming very persistent bands in the Biddulph Valley.

Fig. 7.

Section across the Coal-measures near Knypersley.

By W. Gibson.



Measures between the Crabtree Coal and Winpenny Coal.—These are very poorly laid open for examination in the southern portion of the area, sections being practically limited to the two small streams flowing to the west off Wetley Moor and uniting near Holehouse Farm. In the southern stream the lowest rock visible consists of a flaggy grit inclined to the west at a low angle. This is followed by pale yellow and black shales, with thin bands of hard gannister like grits. At one spot, shown on the map, the sequence is interrupted by a strike fault, but neither the direction or amount of throw can be determined. No signs of the coal seams which it is stated crop out further south in Brookhouse Wood, are met with. The

inclination rapidly increases westward. West of the Rifle Butts the stream near Holehouse Farm has excavated a shallow channel in black shales inclined westward at 35 degrees and containing thin bands of gannister-like grit and an occasional indication of thin coal seams. Grey shales succeed, overlain by a massive reddish and grey grit forming a conspicuous ridge from here to Big Brookhouse Farm. The grit is quarried in a field near the junction of the stream and again to the south of the Rectory. This is no doubt the grit quarried to a small extent further south on the summit of a ridge standing prominently out of the surrounding Glacial deposits between Widowfield and Simfield Farmhouses.

From Holehouse Farm northward practically nothing is seen of the sequence till near Knypersley Reservoir, where black shales containing a seam of coal one foot thick, form the banks of a small dingle north of Tongue Lane Farm. A reddish grit, similar to that near Holehouse Farm and giving rise to an evanescent feature, has been somewhat extensively quarried in the fields west of the Dingle. Very little can be made of the stratigraphy to the north; grey shales crop out along the western margin of Knypersley Reservoir, and black shales in Tinkers Clough succeeded by grey flags well shown in Knypersley Wood.

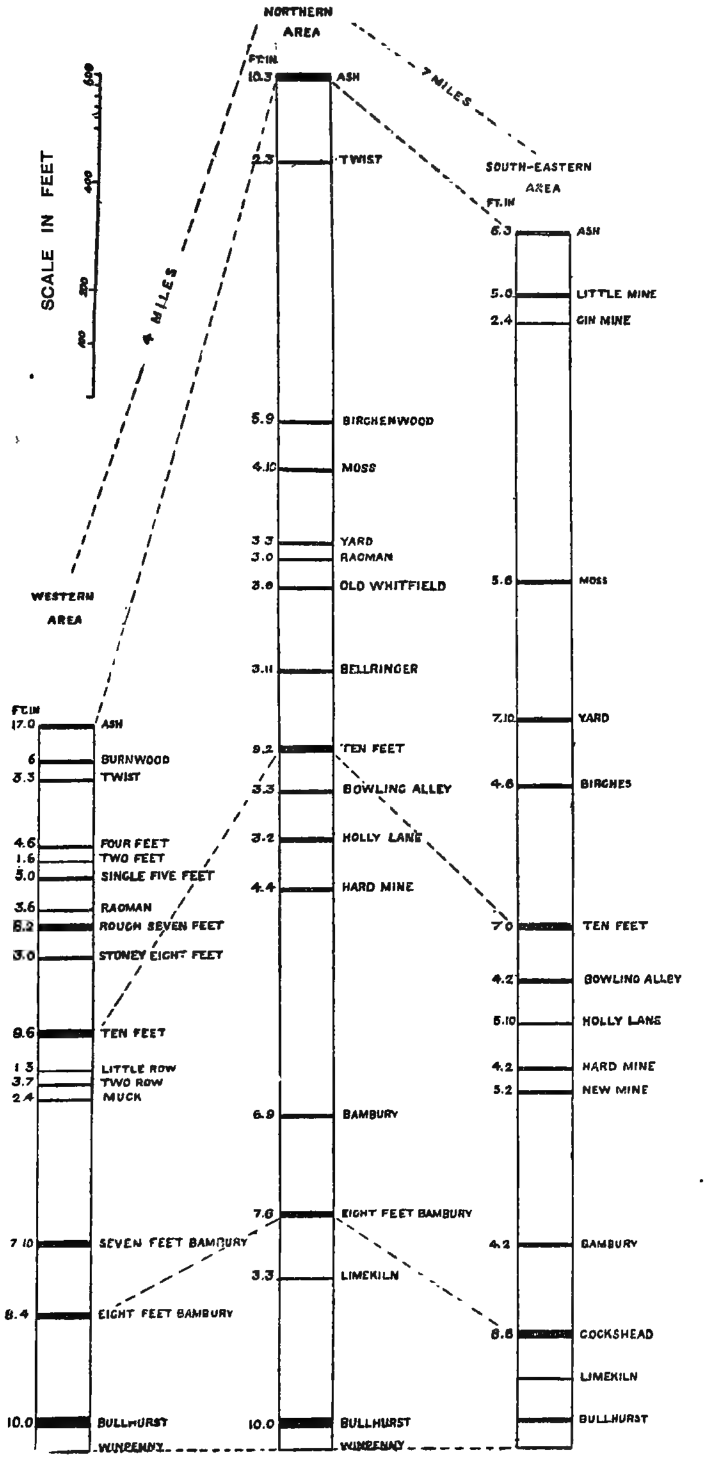
Measures between the Winpenny and the Moss Coal.

This group contains the chief coal seams in the district which are included in the following list:—

Moss or Mossfield Coal.
Yard Coal.
Ragman Coal.
Birches Coal.
Bellringer Coal.
Ten Feet Coal.
Bowling Alley or Magpie Coal.
Holly Lane Coal.
Hard Mine or Sparrow Butts Coal.
New Mine or Stinker's Coal.
Little Mine Coal.
Bambury, or Seven Feet Bambury Coal.
Cockshead, or Eight Feet Bambury Coal.
Limekiln or Whitehurst Coal.
Bullhurst Coal.
Winpenny Coal.

The measures and the coal seams seldom make their appearance at the surface owing partly to a capping of Drift, but chiefly to the soft crumbling nature of the shales; most of the information has therefore to be obtained from the mine workings, of which the records of many of the shaft sinkings will be found in Appendix No. III., and on the sheet of vertical, sections published by the Survey (Vert. Sect. Sheet No. 86). The more prominent features have all been fashioned out of the harder sandstones of which those associated with the Cockshead, Bowling Alley and Ten Feet coals, and the sandstone between the Yard and

FIG. 8.—COMPARATIVE SECTION OF CHIEF COAL SEAMS BETWEEN THE ASH COAL AND THE WINPENNY COAL.
BY W. GIBSON.



Moss coals may be cited as examples. A comparison of the shaft sections of the Chatterley, Whitfield and Ford Green, with those of the Florence, Mossfield and Adderley Green collieries shows that in the former district the sandstones are in the larger proportion. This is indicated at the surface by the greater boldness of the features, and is particularly noticeable in the straight and prominent ridge formed by the Ten Feet Rock between Milton Railway Station and Norton-in-the-Moors. These rock bands form practically the only index at the surface of the outcrop of the seams, reliable information about the crop of the others being exceedingly scanty.

Coal Seams and Associated Rocks.—The strata retain a steady inclination to the west varying between 20 and 30 degrees, but decreasing as the centre of the syncline is approached Faults play a very inconspicuous part at the surface and are most abundant and of greatest throw between Adderley Green and Bucknall (p. 161). In the Ubberley district many faults of small throw, some of them overthrusts (overlaps), cross the measures in a general east and west direction.

Winpenny Coal.—This seam enters the coalfield on the south beneath the Drift north of Hulme village, and remains hidden beneath it or under the Trent alluvium to Knypersley reservoir. Few of the collieries have worked the seam, so that little information is to be obtained about it. In the Chatterley area the seam is described by Mr. Homer * as three feet thick, and is a good household and manufacturer's coal.

Bullhurst Coal.—For information respecting this seam we again depend upon colliery information. In the south-eastern area the coal crops out under the Drift filling the small valley north-west of Willots Wood. In the shaft of the Ford Hayes Colliery, close to the stream, it was at a depth of between 45–50 yards; a shaft 100 yards to the south struck it at a depth of 95½ yards and in a bore hole to the south at 160 yards.† Drift deposits and alluvium conceal the outcrop northward. In the Hanley and Bucknall Collieries it is stated to be six feet thick, and is overlain by grey rock and grey metal. It cropped out in a level 400 yards to the east of the Blakelow and Greasleyside Colliery, and is occasionally ploughed up in a field north of the Abbey. In the Bellington Lane pits, Ford Green, the seam lies at a depth of 482 yards and is seven feet thick, being a first class house coal.‡ In the Whitfield Colliery a crut from the Platt Pit passed through the following seams before reaching the Bullhurst at a distance of 112 yards from the shaft.

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* Iron and Steel Institute, vol. 1875.

† From information supplied by Mr. Richard Haines.

‡ From information supplied by Messrs. R. Heath and Sons.

WHITFIELD COLLIERY.

Section of Crut to the Bullhurst Coal.

	YDS.	FT.	IN.
COCKSHEAD COAL			
Measures	22	0	0
LODGE-ROOM COAL			
Measures	19	0	0
WHITEHURST COAL			
Measures	9	0	0
COAL	0	0	8
Measures	17	0	0
COAL, *Inferior*	1	2	8
Measures	45	0	0
BULLHURST COAL	1	2	0

Cockshead or Eight Feet Bambury Coal.—This is the best known and most frequently sought-for seam on the eastern side of the coalfield, and can be easily recognised by a thin bed of overlying ironstone containing *Carbonicola acuta* in abundance. For information regarding the depth to this seam and its thickness, reference can be made to the published sheet of Vertical Sections—Sheet 86, Nos. 2, 4–6–7, and shaft sections in Appendix No. III. Around Hulme the outcrop is very uncertain owing to the complicated nature of the faulting. Several shafts—shown on the six inch map—are stated to have proved the coals, but the asserted depths do not agree with the faulting proved in the Adderley Green Colliery. Little information can be obtained about its outcrop northward, a matter of small importance, as its depth is proved in many collieries. Throughout the region it retains its character of a first class house coal, it is also used in the blast furnaces and for general manufacturing purposes. Towards the centre of the syncline large areas remain untouched.

Seven Feet Bambury, Bambury, Frogrow, or Froggery Coal.—This is likewise a seam recognised throughout the district and in much request. Its position and thickness will be gathered from the published sections and those in the Appendix. In common with the seams below and many of those above, information can only be obtained from the collieries. On the western side of the district the seam is overlain by a shale containing marine fossils, which have not as yet been found on the eastern synclinal region. It is a good manufacturing, forge, and steam coal, and is also used as a house coal.

Hard Mine Coal.—This is the best coal for the blast furnaces, for which it is mainly utilised. As will be seen from the table (p. 44), some small coals between it and the Cockshead Coal are recognised, but they are not of great importance. The Hard Mine is usually overlain by a black bass or cannel-like shale in which fish remains are numerous, while the marls above contain lean ironstones, with numerous casts of *Anthracomya Williamsoni*.

Holly Lane Coal.—A good house coal recognised throughout the district. In the Whitfield Colliery this coal is duplicated for a short distance by overthrusting.

Bowling Alley Coal.—The coal under this name receives chief recognition in the Longton area. In the Biddulph Valley it is known as the Magpie Coal. It is a manufacturing and house coal. Above the coal there occurs a strong rock in the northern part of the district, which, in the south, is liable to be separated into different beds by shale partings. The rock is a prolific horizon for plants. In the Longton area, at the Meirhay Colliery, the measures in contact with the coal are stated to be strongly impregnated with petroleum.* This coal was intersected by the mineral railway to the Rookery Colliery, Adderley Green, but elsewhere neither the coal or associated rocks are exposed. At Adderley Green a band of limestone showing cone-in-cone structure and containing *Spirorbis* appears to be associated with the coal, and is said to have been passed through in the shafts of the Adderley Green Colliery. The position of the limestone in the railway cutting is somewhat doubtful, but the recent work of Mr. Stobbs† reveals the general occurrence of a horizon containing *Spirorbis* above the Bowling Alley Coal in the following collieries:—

SNEYD COLLIERY.

		FT.	IN.
Mussel band with *Carbonicola* -		—	
Band slightly calcareous, *Spirorbis* rare		0	1
Black shale and mussel band		0	4
Band slightly calcareous, *Spirorbis* numerous -		0	2
Black shale with *Carbonicola*		0	3
BOWLING ALLEY COAL -		—	

UBBERLEY COLLIERY.

		FT.	IN.
Mussel band with *Carbonicola* -		1	0
Hard compact band, slightly calcareous		0	1
Mussel band with *Carbonicola* -	1 foot to	2	0
Spirorbis band -		0	2
Mussel band - -		0	6½
Black shale	-	0	2½
Mussel band	- -	0	0¼
Dark shale		0	7¼
BOWLING ALLEY COAL -		3	5

PARK HALL COLLIERY.

	FT.	IN.
Mussel band	0	9
Spirorbis band -	0	1½
Mussel band	1	0
Spirorbis band	0	2
Mussel band	0	9
Black shale	0	5
BOWLING ALLEY COAL	—	

* John Ward, op. cit. p. 41.
† *Inst. Min. Eng.*, vol. xxii., p. 229, 1901.

WHITFIELD COLLIERY.

	Ft.	In.
Hard black fireclay	—	
Top band with *Carbonicola*	0	2¼
Dark shale, few *Carbonicola* and *Spirorbis*	0	5
Spirorbis bed, few but large *Spirorbis*	0	2
Black shale with *Carbonicola*	0	4
Black shale, mussel layers and stone bands with *Spirorbis*	0	2
Black shale with mussel layers	0	6
Spirorbis bed, rich in *Spirorbis*	0	1¾
Black shale	0	0¼
Mussel band	0	1½
BOWLING ALLEY COAL	3	3

BROWN LEES COLLIERY.

Spirorbis band, *Spirorbis helicteres, Carbonia*	0	2
Black shale and mussel layer, *Spirorbis* in lower ½-inch	1	0
Spirorbis bed, *Spirorbis helicteres* numerous	0	1½
Mussel bed, *Carbonicola*	0	1
MAGPIE COAL	—	

Ten Feet Coal.—This seam runs regularly throughout the district. Its outcrop may be traced by the overlying sandstone, which frequently forms well-marked ridges. The Ubberley valley from Adderley Green to the New Ubberley Colliery has been excavated along it. The rock then emerges in the conspicuous hill of Bucknall, but northward lies in part beneath the alluvium of the Trent to near Milton, from which it rises near the railway station into a bold ridge continued northward to Norton-in-the-Moors, when it again ceases to be distinguishable, but appears again as a massive rock to the east of Brindley Ford. The rock contains pockets of hæmatite and highly ferruginous shales, which by weathering impart a red colour to the soil, that is very noticeable in the fields to the east of Ford Green. The rock has been quarried in places near Milton, Stanley Fields and Bemersley.

The Ten Feet Seam furnishes a steam, forge and manufacturing coal and a seconds house coal.

Bellringer or Stony Eight Feet.—This is recognised in some of the shaft sections but is not such an important coal as on the western side of the coalfield. In the Whitfield area it is 3 feet 6 inches thick and is used in the blast furnace. In the northern anticlinal region it becomes the Stony Eight Feet or Ten Feet Rider Coal.

Birches or Old Whitfield Coal.—Known as the Birches Coal in the southern part of the district, where it varies from 3 feet to 4 feet 6 inches in thickness, this seam is renamed the Old Whitfield Coal at Whitfield, where it furnishes a blast-furnace, steam and manufacturing coal, and is also used for household purposes.

Ragman or Hams Coal.—In the Florence Colliery the Hams and Yard coals are only between 3 and 4 feet apart but further northward are separated by several feet of shale. The Ragman is said to be a good house coal.

Yard Coal.—In the Florence Colliery this coal occurs at a depth of 815 yards, and gives the following section:—

SECTION OF YARD COAL, No. 2 SHAFT, FLORENCE COLLIERY.

	FT.	IN.
Tops	2	8
Pricking	0	4
Bottoms	4	10

At a depth of 833 yards a coal 4 feet 5 inches thick was passed through. This coked freely, which is an unusual character of the coals over the eastern area. The shafts of this colliery have been carried to a depth of 891 yards, being the deepest in the district.

In the Longton and Adderley Green areas the coal is overlain by sandstone, with thin partings of shale, described as grey in colour in the record of the Florence shafts, and as red rock in those of Adderley Green, which were commenced in it and reached the Yard Coal at 30 yards depth.

The same kind of strata are exposed in the by-lane from the Bentilee Colliery to Pool Dole. The Yard Coal crops out near the bottom of the lane, and is almost immediately succeeded by red shales with calcareous nodules, in which the small fossil *Scaldia minuta* occurs. Above these, massive red sandstones form the crest of the hill, and can be traced southward to Mossfield Farm. Further south, at Weston Sprink, north-east of Normacot Station, red clays are excavated for bricks. These have been carefully examined from time to time by Mr. Ward, by whom the following section was measured:—

MARL PIT, WESTON SPRINK, NORMACOT.

	Thickness. FT.	IN.
Boulder clay	2	0
(*a*) Irregular band of calcareous rock and purple clay with marine fossils	1	0
(*b*) Calcareous nodules, containing marine fossils	5	6
(*c*) Thin band of Shale, marine fossils		2
Bed of impure coal or smut	1	2

The band of calcareous rock, the calcareous nodules and shale below contain a marine fauna, given on p. 317, also the bivalve, recognised by Dr. Wheelton Hind as *Scaldia minuta*. The stratification is irregular and the fossils by no means numerous. The band of calcareous rock is light-coloured or blood red, the latter variety resembling the Froghall Ironstone for which it was mistaken, and numerous shafts, now dotted over the Sprink, were sunk in the hope of its proving of value. Although the strata at Weston Sprink closely resemble those exposed in the by-road at Bentilee, and *Scaldia minuta* occurs in both, yet if they are on the same horizon it seems difficult to reconcile their position at Weston Sprink with the depth to the Birches Coal, as proved in No. 2 shaft of the Weston Coyney Colliery, where this seam is 269 yards beneath the surface and is inclined to the south-west at 18 degrees. The strata must either turn up sharply, a fact partly supported by the dip of 25 degrees in the marl pit, or there must be faulting, though what the amount is it is difficult

to say. That these red beds occur between the Yard and Moss Coals receives some support from similar beds, being found on the same horizon south of the New Seven Feet Mine Pit of the Chatterley Whitfield Colliery.

Moss or Mossfield Coal.—This is one of the best house coals in the Longton district, where it is nearly 6 feet thick, but the roof is sometimes bad, while north of Hanley the seam is, in addition, much thinner. In the Glebe Colliery, Fenton, it has a cannel, 3 feet thick, above it; at the Sneyd Colliery a cannel, from which a few *Lingulæ* have been obtained, occurs 3 feet 10 inches thick, 10 yards below the coal. The seam is also known as the Easling.

Measures between the Moss and Ash Coals.

The seams in this group are of much less value than those of the underlying group. The Birchenwood Seam is far the best, but it is chiefly mined about Kidsgrove, at the northern end of the syncline; while in other collieries over the area it is not recognised. The other seams are far more difficult to recognise from place to place than was the case with the majority of those below the Moss, some only possessing a local significance. To balance the inferiority of the quality of the coal seams the group possesses valuable ironstones, of which the Burnwood stone is the best, ranging from 1 foot to 1 foot 6 inches in thickness.

Very little opportunity is afforded for studying the character of the associated strata, which is mainly supplied by shaft sections. Since these records have in past years been very irregularly kept, and in many instances drawn up by persons ignorant of geological terminology, the information is mainly confined to the depth and thicknesses of the seams of coal.

Birchenwood Coal.—A first class house coal, but, except in the Kidsgrove area, not in much request. The only locality we know of where the measures can be seen is in the road from Foxley Bridge to Cobridge, north of Holden Lane Farm. The overlying shales contain many ironstone nodules with the remains of plants.

Doctors Mine.—Recognised in some of the shafts in the south-east (see Appendix No. III).

Gin Mine, and Twist or Pottery Coal.—A considerable mass of strata, amounting to over 160 yards at Sneyd, without any important seams, intervenes between the Birchenwood Coal and the Gin Mine. The chief interest attached to this horizon is the occurrence of a grey marl or clunch a few feet below the coal, which in the Speedwell Colliery contained a rich marine fauna, but until recently was not found elsewhere (see Part III. p. 319.)

Burnwood, Little Mine, or Newmine Ironstone and Coal.—The Ironstone lies immediately on a coal from 4 to 5 feet thick, used as a manufacturing coal. The ironstone is described as a semi-black-band ironstone or clay-band ironstone, and is in much request around Newchapel. The Newmine Ironstone immediately overlies the Burnwood stone.

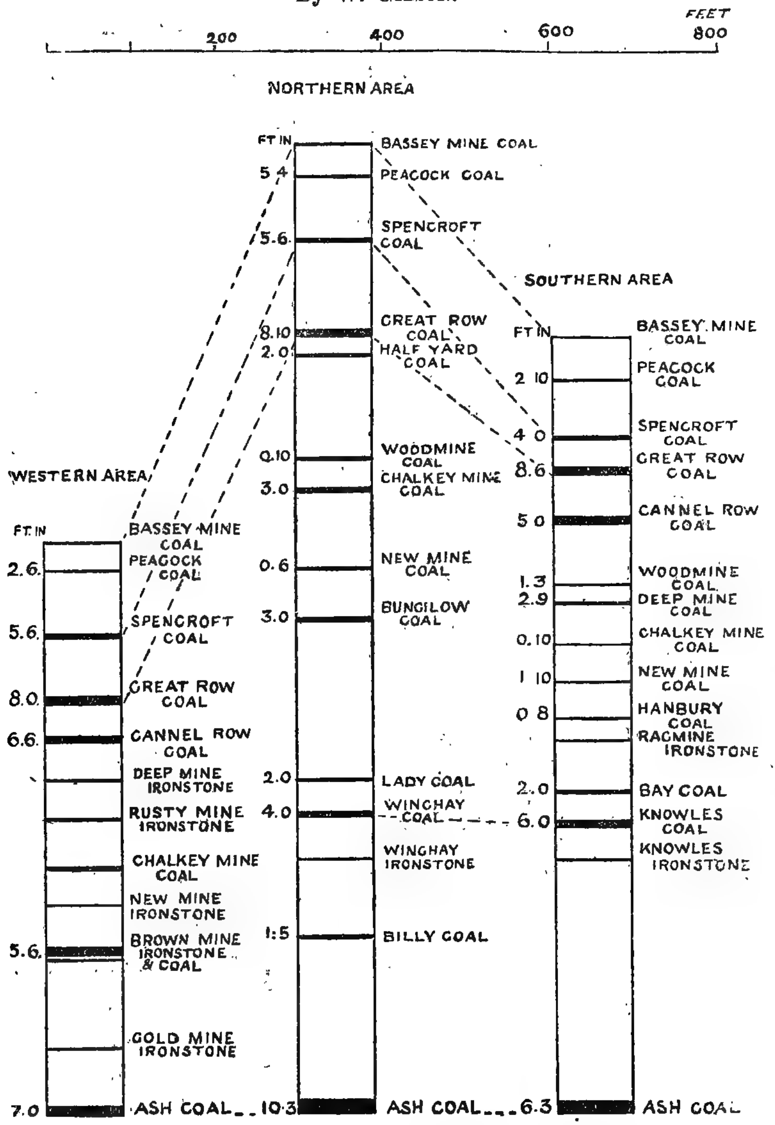
Measures between the Ash Coal and Bassey Mine Coal.

These are sometimes known as the "Pottery Coal and Ironstone measures" from their containing many seams of fierce-burning coals, cheaply got and suitable for use in the pottery kilns. There

FIG. 9.

COMPARATIVE SECTION OF THE CHIEF SEAMS OF COAL BETWEEN THE ASH COAL AND THE BASSEY MINE COAL.

By W. GIBSON.



are also many bands of clay ironstones, formerly in much request. On several horizons, but notably near the summit, the

marls have proved of great commercial value and have, therefore, been extensively excavated for bricks and vessels used in the pottery trade, we consequently know more of the characters of this portion of the sequence than any of that below the Ash Coal. We will first give the characters and distribution of the seams of coal in ascending sequence, and afterwards the sections in which the associated measures can be studied.

Ash or Rowhurst Coal.—This is a seam varying from 6 to 9 feet thick, and forms a good house coal, being also used for manufacturing, steam and forge purposes. It is sought for over the entire synclinal area owing to its being cheaply won.

Knowles or Winghay Coal.—Used for manufacturing purposes, varying in thickness from 4 to 8 feet.

Bay or Lady Coal.—A thin seam but of considerable value for correlation purposes owing to the constant occurrence above it of a band of shale containing marine organisms.

Bungilow Coal.—A thin coal of poor quality recognised only in the northern part of the region, where it has a rock, frequently of a red colour, above it.

Chalky Mine Coal and Ironstone.—The coal is only of average quality, but directly underlies the ironstone of the same name.

Deep Mine Coal and Ironstone.—The coal is known chiefly in its association with the Deep Mine Ironstone.

Wood Mine Coal.—Recognised in some shaft sections in the south-east, and as a Cannel Bass in association with ironstone in the more northerly portions of the area, where, it was formerly used for oil-making.

Cannel Row Coal.—Above the Wood Mine we come to a series of very persistent seams which from their association with marls used in the manufacture of coarse pottery, and to their suitability for burning in the kilns, have been largely worked

The Cannel Row Coal varies in thickness from 5 to 6 feet, and is a steam, pottery, and seconds house coal. It is overlain by Cannel and Ironstone, known sometimes as the Cannel Row Half Yards, consisting of 1 foot 6 inches of coal, 3 to 6 inches of Peel Cannel, and 1 foot 6 inches of strong Cannel and Ironstone. The Cannel was used for oil making, yielding from 56 to 60 gallons of crude oil to the ton (C. J. Homer, Proc. Iron and Steel Inst., 1875).

Great Row Coal.—Varies between 5 and 8 feet thick. In the northern part of the area it is overlain by a black cannel and bass, said to have yielded over 30 gallons of oil to the ton. The coal is used for house, manufacturing, steam, pottery, and iron-making purposes.

Spencroft Coal.—A potter's coal, but also used in the forge.

Peacock Coal and Little Row Coal.—The two seams are similar in general properties to the Spencroft, but the associated marls are also of much value.

Distribution of the Measures.—In the south-eastern part of the coalfield the Ash Coal was formerly worked by open cast to the north of Anchor Road, Longton, 150 yards to the north-east of the Speedwell Colliery. The Knowles Ironstone and Priorsfield Coal were also formerly obtained in open workings to the west of Ashwood, but the best section of these and their associated measures is afforded by the sections in the mineral line between Weston Coyney Road and the Uttoxeter branch of the North Staffordshire Railway. The Knowles Coal is here repeated to the north-east by a small fault crossing the railway 150 yards north-east of the reservoir. Some thin bands of ironstone above the Knowles Coal contain a small fossil resembling *Carbonicola Vinti*, and a similar looking shell is found in the shales associated with the Priorsfield Coal, a section of which is visible near the junction of the mineral line with the main line.

Between the north end of the Meir tunnel and Normacot station the railway cutting intersects a coal, two feet thick. This is succeeded by black shales and mottled red and grey shales seen over the mouth of the tunnel. The exact horizon is not clear.

To the west of Pool Dole a nearly continuous line of marl pits extends from Fenton Park to Golden Hill. The following section was measured in the Fenton Park Marl Pit :—

SECTION IN FENTON PARK MARL PIT.

Character of Strata.	Thickness. Ft.	In.
Black shales with occasional nodule of ironstone	2	4
Sandy shale - - - - -	4	0
Yellow shales with thin ironstone bands	3	6
Black shales and thin coals	7	0
Clay with ironstone nodules	4	0
Grey rock, plant remains		6
Clay with ironstone nodules	2	0
Bass and fireclay mixed - -	6	0
Grey clay with ironstone nodules -	13	0

The exact horizon of this section is uncertain. An old shaft situated in the floor of the marl pits intersected the Knowles Coal at 76 yards, and from a comparison with the section of No. 3 shaft, Oldfield Colliery, it will be seen that the measures are situated between the New Mine Coal and the Chalky Mine Coal.

Specimens of the ironstones in the lower part of the section were submitted for microscopical examination to Dr. Teall, who states that

"The rock is composed almost entirely of spherulites of siderite. The spherulites measure from 1 to 1·5 mm. in diameter, and are usually composed of 8 or 10 individual crystals. They are often stained brown at their

margins, in consequence of the decomposition of the siderite and the oxidation of the iron. Sometimes the spherulites are in close contact with each other, and sometimes there is a small quantity of brown interstitial matter. The insoluble residue consists of a very fine mud. The rock is a spherulitic siderite."*

The microscopical characters are very similar to those of a band of Dolomite which replaces the Seven Feet Seam of the Wirral Colliery in the estuary of the Dee, and described by Mr. Strahan.†

The specimen examined by Dr. Teall showed on an analysis by Dr. Pollard 38·7 per cent. of metallic iron (Summary of Progress, 1899, p. 127). A sample, taken from four bands of nodules occurring over a surface of nine square feet on the northern part of the marl pit, showed the total amount of iron present to be 35·3 per cent.

The marls were used for bricks, but are no longer worked in this pit. Two hundred yards to the south a fresh opening has been made and the clays are manufactured into bricks, saggers, etc. At the top of the section two thin coals separated by three feet of black shale overlie several feet of light grey marls with nodules of siderite. The plans of the Pool Dole workings show that a small fault separates this excavation from the Fenton Park Marl Pit. The horizon of the marls is therefore uncertain, but the sequence closely resembles the lower part of that shewn in the Queen Street Marl Pit, 150 yards to the south.

SECTION OF MARL PIT, QUEEN STREET, FENTON.

Character of Strata.	Thickness. Ft.	In.
Black shales with ironstone nodules - -	16	0
Grey shales -	1	8
Grit with many plant remains	1	0
White clay ·	3	0
COAL - - -	2	0
Black shales	3	6
COAL - - -	1	0
Grey marl with nodules of siderite	3	0

There are few other open sections in this area, but a red sandstone is exposed in an old quarry 150 yards south of the Top Pits, Berry Hill. As the Knowles Coal crops out a few yards to the north, the grit probably corresponds in position to one forming a conspicuous feature further north in the Chell district. (p. 73).

The marls above the Peacock Coal are well exposed in Warrington's Marl Pit, where they contain many nodules of siderite.

The depths to the coals in the Berry Hill district are furnished by the following pits, the depth from the surface being in yards. *Top Pit*: Knowles Coal 50, Ash Coal 160, Moss Coal 430, Yard Coal 529, Birches Coal 544; *Bush Pit*: Great Row Coal 11;

* Summary of Progress of the Geological Survey for 1898, p. 127.
† Q. J. G .S. Vol. lvii. 1901.

Railway Pit: Bassey Mine Coal 82, Peacock Coal 98, Spencroft Coal 129, Great Row Coal 148, Cannel Row Coal 168.

North of the Trent the measures between the Peacock and Bassey Mine Coals are opened up in numerous marl pits, of which the character is shown in the measured sections Nos. 49-50. Appendix III. Of the strata below the Peacock Coal exposures are less numerous. The most southerly is the Northwood Marl Pit to the west and close to the Hanley Borough Colliery. If no fault intervenes between the marl pit and the colliery the section lies about the horizon of the Winghay or Knowles Ironstone. Accurate measurements are not possible owing to the slipped nature of the sides of the marl pit and to the evident, but partly concealed disturbances, affecting various portions of the excavation. Drift and refuse material also hides much. In the floor of the pit grey grit bands and grey shales with plant remains rest on black shales containing a thin band of ironstone. Pale grey marls, in which lies a lenticular seam of coal two feet thick, continues the upward succession. In the south end of the excavation, which is separated from the north end by talus, the top of the section consists of about 12 feet of black shale with thin bands of grey ironstone containing *Carbonia* and *Naiadites*. These rest on grey marls with nodules of siderite underlain by sandy shales with thin bands of ironstone containing *Naiadites*.

The deep cutting of the Leek Road to the east of the Burslem Cemetery intersects the Ash Coal and also an ironstone, possibly the Brown Mine. The latter yields excellent casts of *Carbonicola*.

About one quarter of a mile to the south the Scotia and Sneyd Green marl pits, Sneyd Green, situated on the upthrow side of the North and South Fault (p. 162), are excavated in the marls associated with the Winghay Coal:—

SECTION OF SCOTIA AND SNEYD GREEN MARL PIT, SNEYD GREEN.

Character of Strata.	Thickness. Ft.	In.
White clay - - -	5	0
Black shales, thin coal and ironstones	8	0
Grey marls - - - - -	18	0
Black shales, fish scales, *Carbonia*	1	6
Grey marl -	2	0
Ironstone, in bands	1	10
Grey marl	2	0
Black shale		3
Grey marl	2	0
Black shale -		3
Grey marl to bottom of excavation	10	0

For half a mile to the north of the Sneyd Colliery the surface of the ground is almost covered with the refuse heaps of old coal workings. The outcrops of the coals from the Chalky Mine and the Bassey Mine are shown on Cope's Map of which mention

has been made before (p. 19) but the outcrops are no longer traceable.

To the north of the Bank Top Colliery the marls and shales above the Bungilow Coal are being extensively quarried for brick-making, etc. About 16 feet of grey shale and impure fireclay are overlain by a coal 3 feet thick, resting on a thin bed of fireclay. Above the coal the section is continued in black and grey shales with a bed of rock 10 feet thick towards the middle. The seam of coal is probably the Bungilow Coal. In the shallow excavation near the roadside nodules of siderite, lying in grey and yellow marly shales are fairly abundant. A little further to the north of Banktop the soil assumes a bright red tinge, which is found to be due to the weathering of a sandstone. The latter caps a shallow pit 200 yards to the west of the High Lane Colliery. In this, about 10 feet of sandstone, red on the outside, rests on about 25 feet of red and yellow clays containing thin bands of a red spotted grit. The sandstone can be readily traced, by the accompanying feature, to Spring Bank, a little north of which its continuity is broken by a small east and west fault coincident with a small east and west valley. The grit has been largely quarried on the north and south sides of the road leading from Spring Bank to Little Chell. The red colour is probably derived from the oxidation of the iron contained in the nodules of ironstone and thin bands and wisps of a highly ferruginous shale which are intercalated between the grit bands. The grit can be traced northward as far as the church at Newchapel, partly by the feature and partly by the red colour of the soil. The rock is also seen in an old quarry to the north of Turnhurst and in a road-cutting a little further to the north.

The mineral line from Pitts Hill to the Whitfield Collieries gives a nearly continuous section from the Bungilow Coal down to the Ash Coal. It is only, in fact, interrupted by the tunnel south of Great Chell. On the west side of the tunnel the cutting shows two bands of grit, between which grey marls and two thin coals are interposed. The higher seam of coal is the Bungilow, which is 26½ yards deep in the Good Hope Pit, near the western termination of the cutting. The distinctive feature of the section is the presence in the grey marls of bands and nodules of a red clay-ironstone. These resemble the bands between the Moss and Yard Coals at Weston Sprink, but no fossils were found in them. On the east side of the tunnel, in which the Winghay Coal was intersected at 150 yards from the mouth, a continuous, though faulted, section down to the Ash Coal is laid bare. (p. 459, Appendix III). The fault intersected is the northerly extension of the North and South Fault (p. 162), which may be estimated here at forty-five to fifty yards down west. Though noticed in the section (Appendix) as two faults, the lower of the two is merely a gliding plane, the main dislocation occurring above the grey flags. A considerable amount of compression has taken

place in the proximity of the faults, as is shown by the breaking up of a thin seam of coal above the orange grit of the section, and its being squeezed into the shales in the form of stars and streaks of bright brittle coal breaking with a marked conchoidal fracture.

The Rowhurst Coal crops out a few yards to the west of the Engine Pit, and was here formerly raised by a level. A "foot rill" (level) on the Winghay Coal is still visible 300 yards to the south-west of the Oxford Colliery and to the north of the road leading from Great Chell to Brindley Ford.

In an old shaft situated near the Vicarage, Newchapel, the upper seams lie at the following depth in yards: Winghay Coal 41, Winghay Ironstone 55, Brown Mine Ironstone 125, Rowhurst Coal 175, Burnwood Ironstone 235, Twist Coal 252.

As previously stated, the strike to the west of Newchapel is north-east and south-west, and the inclination to the south-east. The same direction and inclination are to be seen near Bullock's Farm in the cutting in the Mineral Railway from Black Bull to the Birchenwood Collieries. The line crosses the strike obliquely, so that correct measurements are difficult to obtain. Several coals, ranging from a few inches to over four feet in thickness, are intersected, but their horizon is doubtful. About midway in the section a fault crosses it obliquely. The jaws of the dislocation are filled with glacial sands and gravels. On the east side the strata arch over to the west and are nearly horizontal when in contact with the fault.

THE SHAFFALONG COALFIELD.

(By G. BARROW.)

On the north-east border of the area previously described is an outcrop of the lowest Coal-measures, some four miles long by rather less than a mile broad. These Coal-measures lie in a syncline of a somewhat unusual type in the Millstone Grits, for though liable to be locally tilted up here and there they generally lie almost flat across the syncline. Towards its edges the beds are somewhat suddenly tilted up, and the enclosing grits crop out at a high angle, and, in some cases, as at Wetley Rocks, are on end, the form of the syncline, along a considerable part of its length, being similar to that of a ship with vertical sides and a flat bottom. This structure is better marked about the centre and south end of the syncline than at the north. At first sight it looks as though this structure was due to the faults shown on the map, but as these have often a comparatively small throw it is more likely that the faults themselves are part of the phenomena of the sudden up-wrench.

Though the exact thickness of Coal-measures present is not known, there are sufficient sections to make it clear that no beds so high as the flaggy sandstones of the grit that underlies the

Woodhead Coal in the adjacent Cheadle area to the east can be present. Consequently there cannot be more than 250 feet of measures, and including only those seams which are all below the Woodhead Coal and have little commercial value.

Only two seams are known to be present. Of these the upper is the highly-sulphurous Stinking or Crabtree Coal which can be recognised by its roof of dark hard shale with *Goniatites* and other fossils. The other lies some fifty feet below the Crabtree, and was worked to a considerable extent many years ago near the farm of Shaffalong, from whence this coalfield gets its name. Different accounts have been given of these workings. So far as can be ascertained the coal was about two feet thick, with a dirt parting in the middle. The bulk of the coal has been taken out near Shaffalong. The workings probably ceased, owing to the thinning away of the coal, for it is seen in three places close by that it is less than a foot thick. First, in the bank on the opposite side of the narrow part of the reservoir; again, in the stream below Lee House, and also in the base of the fence due north of the house. Moreover, some trial pits were sunk to the south-east of Shaffalong, and the coal found to be of no value. These facts confirm the evidence from all the workings for the Froghall Ironstone in the area to the east, which show that all the seams below the Woodhead, except the Crabtree, are very impersistent. Whether this seam be present or not the horizon at which it occurs is found over the greater part of the syncline. The coal is seen again on the east side of Westwood Pool, and was worked to a small extent, although obviously too thin to pay. It is much more difficult to ascertain the extent of the Crabtree Coal. It was pierced several times in the shafts about Shaffalong, but does not occur on the west side of the valley in this neighbourhood.

A seam was worked at Coalpit Ford. The section in the stream suggests that this must be the Crabtree, for a fault throws down the associated beds against shales above the First Grit, and unless the throw is very small it would be too high for this seam to be the lower or Shaffalong Coal. This view is confirmed by the thickness of dark shales above the coal. There is a considerable amount of sandy material between the two coals which is here missing. In the southern end of the syncline the horizon is still more difficult to fix. A coal was worked near the road on the west side of Wetley Abbey, and a series of boreholes were put down close to the Abbey to prove this coal, but no details were obtained to show which it was.

Thus it will be seen that there is practically little or no coal of any commercial value, under present conditions, in the Shaffalong valley. If some cheap and effective means could be discovered of washing the pyrites from the Crabtree Coal that seam might in time become of some value, for it burns well and cokes well. But as mentioned above, the extent of this coal is very difficult to ascertain. Some good sections of the beds

associated with these coals may be studied in the stream sides in many parts of the area especially about the reservoir near Wall Grange, where a nearly complete section of all the beds present may be made out.

The exact mode of ending off of the Shaffalong syncline is difficult to determine. The eastern side is bounded by a fault, and it is probable that there is a corresponding fault on the west side. These faults would cut each other out, and thus end the syncline. For some little distance to the south of this it is impossible to make out the minor details of the Coal-measures, as a considerable part of the area is covered by Bunter Sandstone.

THE BIDDULPH VALLEY, WITH THE EXTREME NORTHERN END OF THE ANTICLINAL REGION.

(BY C. B. WEDD.)

The Red Rock Fault bounds the western or anticlinal tract of these Coal-measures on the west and north; while a fault running roughly north and south, in part along the axis of the anticlinal uplift of Mow Cop, forms the eastern margin.

West, north and east the Millstone Grit limits the measures of the Biddulph Valley.

The upper part of the Chief Coal-bearing Series is not represented in this most northerly part of the coalfield, as the higher beds are cut out by the Red Rock Fault on the west, and in the east have cropped out further south in the bend of the syncline. The area comprises all the coals from the Birchenwood down to the Cannel Row on the west side of the anticline, and from about the Mossfield downwards in the Biddulph Valley.

As in the rest of the coalfield, the lower measures consist chiefly of grey and dark shales with thin nodular bands of ironstone of no value, alternating with marls, fireclays, coal-seams, sandstones, often of considerable thickness, thin beds of flaggy gannister, and a few thin grits of coarser grain. Occasionally the sandstones have a reddish hue, and are associated with red and purple shales, but the dominant colour of the whole series is grey, and the term "Grey Series," already used for the strata up to the Bassey Mine, is equally applicable to this part of the coalfield.

No detailed sections of colliery-shafts could be procured for the measures of the Chief Coal-Bearing Series in this district, the only shaft-sections available being incomplete ones of the old Towerhill and Bradley Green collieries, and a detailed section

of an old shaft at Lea Mill Forges in the lowest measures.* Beyond the last named, no records have been kept of the shafts which once worked the Crabtree and Little Row coals.

The thickness of the Coal-measures varies, there being a marked thinning out westward in the Biddulph Valley, and also southward, but probably to a less extent. The Horizontal Section (pl. 1, fig. 1) gives no adequate idea of such south-westerly thinning, because it is drawn nearly at right angles to the direction of attenuation, and does not traverse the horizon at which this attenuation is greatest. Probably 2,500 feet is a fair estimate of the thickness of the Coal-measures from the Magpie Coal to the top of the First Grit at Bradley Green; of this the thickness from the Winpenny Coal to the First Grit is about 1,500 feet. These figures diminish for the western and southern parts of the district.

If, as it seems probable, there is any increase of sandy material here, as compared with the southern part of the coalfield, this northerly increase of sandstone is by no means due to a general thickening in this direction of the same beds of sandstone which occur further south. Thus the thick Bambury Rock, overlying the Seven Feet Bambury Coal elsewhere, has dwindled to only five feet; and the Ten Feet Rock above the coal of that name is only six feet thick at Hall o'Lea and four feet at Tower Hill. On the other hand a red sandstone is developed to as much as 100 feet in thickness below the Ten Feet Coal in the eastern part of the Biddulph district, but thins out westward. It evidently represents the Bowling Alley Rock of the south-eastern area. The Bullhurst and Winpenny rocks have also probably attained to greater dimensions in the Biddulph Valley.

Below the Winpenny Coal several more or less thick beds of sandstone occur. These form more conspicuous features in the gently-dipping eastern limb of the Biddulph syncline than in the highly-inclined beds of the western limb of the same fold. The most noticeable of these sandstones is one half-way between the Winpenny and Crabtree coals, which is recognizable at the surface on either side of the valley.

A thin bed of pebbly grit seems constant all round the western, northern and eastern sides of the valley at about 250 feet above the First Grit: it appears to be a short distance below the Crabtree Coal, and is a useful horizon in correlation. In the eastern and northern parts of the trough a red, purple, and white rock—in appearance similar to the finer-grained beds of the Millstone Grit—comes in between the thin pebbly grit just mentioned and the First Grit.

Though there is no natural stratigraphical break in the sequence of these Coal-measures, the coal-seams group themselves into two unequal divisions. The upper of these comprises all the coals

* Sects. Nos. 25 and 26, p. 431 and p. 86; also *Mem. Geol. Surv.*, Geology of the Country round Stockport, Macclesfield, Congleton, and Leek pages 27 and 31.

down to a small seam thirty yards below the Cannel Row; while the lower group contains only a few seams, including the Crabtree and Little Row, in the lowest part of the Coal-measures. If a small coal 130 feet above the Crabtree be taken as the upper limit, it gives to this lower group a thickness of not very much more than 400 feet. This leaves a thickness of not less than 500 feet of barren measures between this lower coal-group and the lowest coal of the upper group. A belt of ground marked by an absence of old shafts and spoil-heaps runs round the Biddulph Valley and shows the position of these barren strata.

The following are the principal coals in descending order as recognised in the northern end of the coalfield.

North Anticlinal Region, West of Anticline.			North Synclinal Region, Biddulph Valley.					
Seam.	*Thickness.* Ft.	In.	*Seam.*	*Thickness.* Ft.	In.		Ft.	In.
Birchenwood Coal -	5	0	No information obtained.					
Little Row Coal -	3	0						
Yard Coal	4	0						
Rider Coal - -	3	0						
Four Feet Coal -	4	0						
Ragman Coal - - -	3	0						
Rough Seven Feet Coal	7	0	Rough Seven Feet Coal - -	6	0			
Smithy Coal -	1	8						
Stony Eight Feet Coal	7	0	Stony Eight Feet Coal -	6	0	to	7	0
Ten Feet Coal - -?	10	0	Ten Feet Coal	5	6	to	7	0
Two Row (Magpie) Coal	4	6	Magpie Coal	5	0	to	5	7
Holly Lane Coal - -	3	3	Holly Lane Coal	3	0	to	4	6
Bowling Alley Coal -	3	6	Bowling Alley, Sparrow Butts, or Hard Mine Coal - -	5	0	to	6	0
			Muck Row Coal	0	10			
Johnny Galley Coal (in three seams)	3	0	Stinking Coal (in three seams) -	3	0			
			Bright Coal (Falls Colliery) -	1	9			
			Ragman Coal (Falls Colliery)	2	0			
			Ironstone Mine Coal -	2	3	to	3	0
Seven Feet Bambury Coal - - -	6	0	Froggery, Frog-row, or Seven Feet Bambury Coal	2	3	to	5	3
Eight Feet Bambury Coal -	9	0	Newpool, or Eight Feet Bambury Coal-	7	6	to	9	0
			Limekiln, Sudden or Whitehurst Coal - - -	?				
Bullhurst Coal - -	4	6	Bullhurst Coal -	?		to	6	0
Winpenny Coal -	3	0	Winpenny Coal	3	0			
			Brick-kiln Row Coal -	1	6			

North Anticlinal Region, West of Anticline. Seam.	Thickness. Ft. In.	North Synclinal Region, Biddulph Valley. Seam.	Thickness. Ft. In. Ft. In.
		BEE COAL - -	?
SILVER MINE COAL - -	2 0	SILVER MINE COAL	3 0
CANNEL ROW COAL - -	3 0	CANNEL ROW COAL	?
		CRABTREE COAL, OR FOUR FEET COAL	3 0 to 4 0
		LITTLE ROW, OR TWO FEET COAL-	2 3 to 3 0
		(FEATHER EDGE COAL)-	1 0

The measures in the western limb of the Biddulph syncline have a steep inclination, the coals on this side being regarded as "rearers." On the eastern side of the valley the beds have a much more gentle dip, and the coals are worked as "flats."

On the whole, the beds in this valley show but little disturbance by faulting, especially on the western side. Such dislocations as do occur are of no great size, but occasionally in the neighbourhood of Bradley Green a narrow belt of ground is shattered for short distances. West of the Western anticline the Coal-measures have a rather high westerly dip, and are more faulted.

The horizontal section (pl. 1, fig. 1) illustrates the sequence and structure of the Carboniferous rocks of the Biddulph Valley and the Western anticline. It is based upon ascertained outcrops, the general dip of the strata, and the depth of the Eight Feet Bambury Coal in the level course of the Bradley Green Colliery. The structure of the ground and the strike of the beds are remarkably regular; but as local modifications of dip, not represented in the section, probably occur, the thicknesses of strata as shown in the section are not always trustworthy.

Though no such natural sub-divisions exist, the Coal-measures will, for convenience, be described here in two groups, the base of the Winpenny Coal, the lowest of the more important seams, being taken as the line of division.

Measures below the Winpenny Coal.

As far as can be determined without complete sections, and in a series varying somewhat in thickness, the following general section gives the relative position of the coals and other important beds, in the northern part of the Biddulph Valley; but the thicknesses are for the most part only roughly approximate:—

Character of Strata.	Thickness. Ft. In.
WINPENNY COAL - - - -	—
Sandy shales and marls, with thin beds of flaggy sandstone About	170 0
BRICK KILN ROW COAL- - - -	
Sandy shales and marls, with sandstone; a bed of pottery marl at the base - - - - About	20

Character of Strata.		Thickness. Ft.	In.
SILVER MINE COAL		3	0
Sandstones and shales	About	90	0
CANNEL ROW COAL		3	0
Shales and sandy shales		90	0
SMALL COAL			
Dark shales, with thin sandstones and flaggy gannister	About	250	0
Bed of whetstone		?	
Dark shales, with thin sandstones and flaggy gannister	About	270	0
SMALL COAL		1	8
Warrant Thin sandstone Shales Shales, with ironstone-nodules (*Goniatites, Pterinopecten, Lingula*,		130	0
CRABTREE OR FOUR FEET COAL		3 to 4	0
Warrant Thin pebbly grit, not far below coal Dark shales		61	0
SMALL COAL		1	0
Dark shales		59	0
LITTLE ROW OR TWO FEET COAL	2 ft. 3 in. to	3	0
Grey marl	About	8	0
Purple sandy shales	"	7	0
Red, purple and white sandstone	"	40	0
Dark sandy shales, with small COAL	"	100	0
COAL		1	0
Purple, micaceous shales		4 or 5	0
First Grit			

As the coals below the Winpenny are no longer worked in this district, the streams alone give any complete idea of the sequence of these measures, apart from the shaft-section at Lea Mill Forges, north of Biddulph (p. 86). Though the material available does not permit the complete sequence to be made out in detail, there is probably no part of the series unrepresented in stream-sections.

Of the two small groups into which the coals below the Winpenny naturally fall, the upper consists of at least five minor seams, some formerly worked; the other of four or five coals, the "Wild Coals" of Biddulph, mostly small, lying above the First Grit. Only two of these are of any importance, the Little Row or Two Feet and the Crabtree or Four Feet.

A coal about 1 foot thick at the southern end of Congleton Edge, in the position of the Feather-edge Coal further north, is separated from the First Grit below by a few feet of purple sandy shale. No trace of the Froghall hæmatite has been noticed. Grey shales, sandy shales, and grey marls, with occasional thin beds of gannister, and apparently one thin coal, the whole probably about 100 feet in thickness in the eastern part of the Biddulph Valley, overlie this lowest coal, and are there succeeded by a thick bed of grit or sandstone. This rock attains a thickness of 40 feet or more in the north where it makes a bold feature, the size of which diminishes

gradually southward, in which direction the rock doubtless becomes attenuated. Though so prominent on the east side of the valley, it does not anywhere appear at the surface on the west, except in the most northerly part of its outcrop, but seems to have died out westward. It is red, purple, and white in colour, often micaceous, variable in grain, and similar in appearance to a rather fine-grained Millstone Grit.

Green states that it holds about the same place as the Woodhead Hill Rock of Lancashire.*

The incoming of this sandstone, and an increase of muddy sediment beyond its limits of deposition, may explain the greater distance of the Crabtree Coal from the First Grit in this district, as compared with the south-eastern part of the Coalfield (p. 57); if, as seems probable, the coal of this name is really the same seam throughout.

The rock just described is succeeded in the north by a few feet of purple micaceous and sandy marl, above which the most northerly section, in Cheshire Brook, shows a nodular bed of impure hæmatite, about four inches thick, which was not found in the next two streams to the south. Above this, some five or six feet of hard blue or grey marl, sometimes resting on a foot or two of gannister-like flags, lies below the Little Row or Two Feet Coal, itself probably less than 20 feet above the thick sandstone. Thick dark shales, with occasional beds of grey, rubbly marl continue the sequence up to a one-foot coal shown in the section at Lea Mill Forges (p. 86).

The shales above the Two Feet Coal contain one or two beds of *Carbonicola* in the northern part of the district; but the exact position of these shell-beds is not certain. More thick shales lie above the one-foot coal above-mentioned.

The bed of hard white grit, usually fine-grained, and containing numerous small quartz-pebbles, which can be traced at intervals all round the Biddulph Valley (p. 97), apparently a short distance below the Crabtree Coal, appears to be the rock described, (p. 243) as often pebbly in a similar position below the Crabtree Coal of Cheadle and Wetley. It attains a thickness of several feet, and is evidently the thin sandstone below the Crabtree Coal in the section at Lea Mill Forges. Shales fill the interval between this rock and the Crabtree Coal, which in this part of the coalfield may be as much as 280 or 300 feet above the First Grit. The roof of this coal contains *Goniatites* and other marine shells in shale and ironstone-nodules (p. 86).

Thick dark shales, with thin bands of ironstone nodules, succeed, and above them is a bed of sandstone. The rest of the measures, up to a coal 1 foot 8 inches thick, 130 feet above the Crabtree, consist of "warrant" according to the shaft-section.

* *Mem. Geol. Surv.*, Geology of the Country round Stockport, Macclesfield, Congleton, and Leek, p. 27.

A series of measures 500 feet or more in thickness follows, in which no known coals occur. These strata consist chiefly of dark shales, with thin sandstones and flaggy gannister. In the middle of them a bed of hard sand-rock, very fine-grained, has been used for making whetstones. It lies about 350 feet below the Cannel Row, and probably about 400 feet above the Crabtree; and is overlain by grey shales with Lepidodendron. Shales and sandy shales probably make up the sequence as far as a small coal about 90 feet below the Cannel Row. This cannel is about the same distance below the Silver Mine Coal. Several beds of sandstone and thin gannister occur about this horizon, at which the outcrops of the harder strata make a decided prominence on the easterly slope of the highly inclined beds in the western limb of the syncline; while in the gently-dipping eastern limb it may be that these rocks are individually thicker, the same strata cropping out in several closely-associated ridges. A strong bed of sandstone lies close to the Silver Mine, which seam, however, is said to be immediately overlain by a bed of pottery marl. Another small coal, known at the Gillow Heath Pottery as the Bee Mine, lies near the Silver Mine, and has a pottery marl above it and a fireclay below; but its exact position with regard to the Silver Mine has not been ascertained. The coal named the Brick-kiln Row is probably about 200 feet above the Silver Mine and 170 feet below the Winpenny. The greater part of the sequence between the Silver Mine and the Winpenny consists of sandy shales and marls, with thin beds of flaggy sandstone.

A comparison of the measures below the Winpenny Coal in this district with the lower part of the sequence in the Cheadle Coalfield (see Part II., p. 243) brings out some points of interest.

In both areas a coal, known as the Crabtree, has a roof of marine shale, and a grit-bed below, which is frequently pebbly, and differs in this respect from higher rocks, so that there is no reason to doubt the identity of these two seams. In the Cheadle Coalfield a thickness of 500 feet of barren measures, with a small coal in the lower part, follows the Crabtree up to the Woodhead Coal, the underlying Woodhead Sandstone forming the highest portion of this barren series. In the Biddulph Valley, if the barren measures are taken to begin from the Crabtree, they consist of some 630 feet of strata without any known coal, except a small one in the lower part. Moreover, the upper part of the barren series of Biddulph reaches a horizon where sandstone plays a prominent rôle in the sequence. Again, marly beds come on above the barren measures in the Cheadle Coalfield, while in the Biddulph Valley, pottery marls and fireclays are worked at the horizon of the Silver Mine and Bee Mine Coals, but not lower. It seems, then highly probable that the barren strata of the lower measures in the Biddulph Valley are, broadly speaking, homotaxial with the barren measures of the Cheadle Coalfield, though it may not be safe to correlate the Woodhead

Sandstone and Coal with any individual rock and coal-seam in this district. There is, however, no doubt that the strata are thickest in the Biddulph area.

Local Details and Sections.—The description begins with the west side of the valley, starting in the south. South of Mow Cop Drift obscures much of the ground, and no sections exhibit the strata of the lowest measures. The outcrop of the Crabtree Coal is said to have been met with in St. Thomas' churchyard, Mow Cop. From a quarter-of-a-mile north-east of the church a thin bed of pebbly grit appears at the surface at intervals as far north as Woolock's Wood. This seems to be the pebbly grit below the Crabtree Coal. The road from Mow Cop to Knypersley, opposite the hamlet known as Welsh Row, shows a somewhat disturbed section, with probably some faulting, in highly-inclined flaggy sandstones and sandy shales, evidently belonging to the horizon of sandy beds at the top of the series of barren measures. These harder beds form small features on the sloping ground running west of Hayhill. The pebbly grit previously described crosses the upper part of the stream which flows south of Hayhill. A coal crops out in the stream a short distance above this rock, and has a roof of pyritous shale, in which, however, no fossils were noted. The seam may, nevertheless, be expected to be the Crabtree. Higher shales appear at intervals lower down the stream. In the field close to the farm thin flags and beds of gannister are intercalated with the shales, amongst which the whetstone, worked further north, should occur. A little higher is a thick bed of white sandstone. In a ditch, north-west of the farm, shales and flaggy beds again appear. Further north, and east of Black Cob, Mr. Cottrell states his belief that the Crabtree was formerly obtained near the outcrop of the pebbly grit as drawn on the map, but no trace of old workings now remains. The stream which flows north of The Falls exhibits the higher beds of this part of the sequence up to the Winpenny Coal. The whetstone-bed, as proved at the surface, crosses this small stream 400 yards west of the Gillow Heath Pottery, near the middle of the group of barren measures. The positions of the Cannel Row and the coal 90 feet below it, as also that of the Silver Mine, have likewise been proved, according to Mr. Peake of the Gillow Heath Pottery. The associated measures crop out in the stream. The shales and flaggy beds below the Brick-kiln Row are seen in a cutting in the road west of the Pottery. They have a high, but variable dip to the east-south-east. The outcrop of the coal was proved in the field north of the road. A "crut" running west-north-west from the pottery traverses the coals and measures down to the Cannel Row, but no detailed section of the strata passed through was available, though the position of the coals was determined.

The whetstone-bed was proved at the surface in the field north of the road further west.

At a quarry in the First Grit, where the road bends abruptly south-west to Mow Cop, a coal one foot thick, the representative

of the Feather-edge Coal, crops out by the roadside. A few feet of purple sandy and micaceous shale separate it from the grit below. A small feature on the slope, about 300 yards west of Beacon House, doubtless marks the pebbly grit below the Crabtree Fragments of pebbly rock lie on the surface, and coal *débris* occurs in a ditch. Northward the feature is cut off by a small fault, and cannot be traced with certainty further in that direction, though a similar feature appears to underlie thin Drift for some distance. In this part of the ground there is no indication that the lower coals have ever been found or worked.

In the clough of Cheshire Brook, east-south-east of Hindswood, the lowest beds seen are dark shales with thin flags of hard, fine, laminated gannister, nearly or quite vertical, but where not actually perpendicular they have a south-easterly dip. Fragments of shale full of *Carbonicola*, though not seen in place, occur in the bed of the stream. The shell-bed must, however, lie above the Little Row Coal. A little higher than the measures last described two small coals crop out among the nearly vertical shales, and seem to have been worked above the north bank. They are evidently the Little Row or Two Feet, and a small coal some distance above it. The stream-section continues upwards in highly-inclined dark shales, with the same strike. Above these, in the south bank east-south-east of Hindswood Farm, a band of pebbly grit, evidently that below the Crabtree Coal, crops out with a dip of about 75 degrees south-east. Along the top of the bank above it several old trial-pits indicate the outcrop of the Crabtree Coal. A little higher up the stream a gap in the section marks the change from a very high south-easterly dip to a gentle south-westerly one. This change of dip denotes the crossing of the trough of the syncline, and also doubtless the position of a fault with a southerly downthrow, which throws the horizon of the Crabtree and Little Row coals against the First Grit seen immediately to the north.

To pass now to the lowest beds seen in this stream in the eastern limb of the syncline and trace them upwards, dark shales, with occasional beds of gannister in their upper part, appear west of the road to Congleton at Lower Overton. These are the shales between the First Grit and the higher thick sandstone (Woodhead Hill Rock of Green). The stream lower down shows a good section of this sandstone. A small coppice clothes the banks of the clough in the lower part of the stream-course. A very few yards above a fence which bounds the north-east end of this wood, at a point in the stream about 370 yards from the road at Lower Overton, the following section down to the thick sandstone is visible under a slipped block of grit:—

		Thickness. Ft.	In.
LITTLE ROW COAL, top not seen - -		0	10
Hard bluish-grey bedded marl with small nodules		6	0
Nodular band of impure hæmatite	about	0	4
Hard purple micaceous marl - -	- seen for	5	0

(Thick red, purple and white sandstone below.)

Downwards in the stream as far as the confluence with a small tributary brook from the east, the higher beds consist almost entirely of grey and black shales with beds of grey shaly marl and thin bands of ironstone-nodules. In the smaller brook, near its junction with the main stream, the same shales appear and contain a thin bed of rather coarse red and yellow grit not recognised elsewhere. Below them, just outside the coppice, which occupies the banks of the clough, a small coal is seen resting on a little white marl. It may be the small seam some little distance above the Two Feet.

The shales immediately overlying the First Grit appear in a stream 200 yards north-east of Alder's Farm, east of Rainow Hill, and mark the most northerly point of the coalfield.

A stream flowing west from Biddulph Park into the Biddulph Brook, south of the latter's junction with the Cheshire Brook, affords a good section up to a short distance above the Little Row. Dark shales with high southerly dip, evidently due to disturbance by a fault, crop out in the stream due south of Higher Overton. To the west the overlying thick purple and white sandstone, varying in coarseness of grain, occupies the bed of the stream as far as that part of Bands Wood which lies north of it. A coal, evidently the Little Row, crops out not many feet above. A little further west two or three spoil-heaps denote the former working of this coal. Still further west the stream shows beds but little higher, as the strike bends round towards the axis of the syncline. The most westerly outcrop shows a bed of *Carbonicola* in shale, probably the same bed as that of which fragments were noted in Cheshire Brook. It is evident that the repetition of the strata of this horizon, seen also at the surface further north in Cheshire Brook, is due to the intervention of the transverse fault from Biddulph Park with northerly downthrow. It may be that the outcrop of the Crabtree Coal under Drift bends round in the field a little further south before reaching the southern stream.

The thick sandstone below the Little Row Coal makes a bold feature running south by Over Biddulph and Biddulph Hall. The slope below it is Drift-covered. The small cloughs draining into the Biddulph Brook hereabouts are all excavated in Drift without reaching solid rock. Nevertheless the Crabtree Coal has been found, and several spoil-heaps roughly indicate its outcrop. Two of these, situated respectively at 650 yards north-west, and 600 yards west-by-north of Biddulph Hall, afford specimens of *Goniatites* in sandy shale or calcareous nodules from the roof of that coal.

The only exposure of the measures in the Biddulph Brook in this part of its course is a small one in the shales above the Crabtree Coal, just visible under Drift at a point 250 yards north of a tributary stream at Lea Mill Forges. Green gives a section of a shaft at Lea Mill Forges, as follows* :—

* *Mem. Geol. Survey.* Geology of the Country round Stockport, Macclesfield, Congleton, and Leek, p. 27.

SECTION OF SHAFT AT LEA MILL FORGES, BIDDULPH.

	Thickness.				
	ft.	in.		ft.	in
COAL	1	8			
Warrant; Thin bed of sandstone; Shales	130	0			
CRABTREE OR FOUR FEET COAL	3	0	to	4	0
Warrant; Thin sandstone; Shales	61	0			
COAL	1	0			
Shales	59	0			
LITTLE ROW OR TWO FEET COAL	2	3	to	3	0
Warrant; Fine-grained thick-bedded sandstone	55	0			
Dark sandy shales, with a little COAL	–	–			

Of this section Green states (*loc. cit.*) "In the roof of the Crabtree Seam were large calcareous nodules with *Goniatites Listeri, Orthoceras, Aviculopecten papyraceus.*"

The tip-heap of the shaft from which this section was taken can be identified about 150 yards from the road, on the north bank of the stream which falls into the Biddulph Brook at Lea Mill Forges. *Pterinopecten* (*Aviculopecten*) and *Goniatites* can still be found in the shale-*dèbris.*

The stream itself shows a fine section of these beds. After passing under the road east of Biddulph Mill it exposes the upper half of the sandy shales and marls above the First Grit, and the thick sandstone below the Little Row. This rock is as usual a massive red purple and white rock of varying grain, but never pebbly. The following is the section of the beds immediately above the sandstone, as seen in the stream:—

Character of Strata.

	Thickness.	
	ft.	in.
LITTLE ROW OR TWO FEET COAL, seen for	0	8
Dark grey sandy rubbly marl, harder below	2	0
Gap	2	0
Grey sandy rubbly marl, as above, about	1	0
Grey and buff laminated marly micaceous grit, about	2	6
Dark grey hard sandy and shaly marl, perhaps	2	0
Purple and yellow laminated flaggy and shaly grit, seen for	2	0
Gap	2	0
Purple and white laminated gannister flags, seen for	1	0

The thick sandstone is seen two or three feet below. Old tip-heaps north of the stream show that the Little Row Coal was here worked from its outcrop. The higher strata in the stream consist principally of dark shales with thin hard bands and beds of rubbly sandy marl.

The small coal above the Little Row in the shaft section of Lea Mill Forges was not detected in the stream, neither was the usual pebbly grit below the Crabtree, though blocks of it lie on

the surface. The most westerly exposure in the banks showed nine feet or more of sandstone, apparently the thin sandstone above the Crabtree.

The brook which flows along the north side of the grounds of Biddulph Grange also exhibits the lowest measures, in part repeated by a fault. For some distance west of the exposure of the First Grit in this brook nothing is seen, and the straight course of the brook coincides with the line of the Spring House Fault. Further west the stream makes a small loop to the south. The pebbly grit below the Crabtree, seen in this loop, has a northerly dip, probably due to disturbance by the fault. Coal-*débris* in the banks of the stream doubtless indicates the outcrop of the Crabtree a few yards further west. A shaft, 100 yards north-east of the stream, and due north-east of Biddulph Grange. was sunk on the fault, which must have a southerly downthrow. The tip-heap contains abundant *Carbonicola*, evidently from the shell-bed some distance above the Little Row, on the north side of the fault. A tip-heap 150 yards north-east of this old shaft marks the position of another, which must have gone down to the Little Row, though no record of it remains.

Seventy yards south-east from where the road from Marsh Green to Biddulph Common crosses the stream the same pebbly grit, brought up northwards by the fault, appears again. The Crabtree Coal apparently crops out close to the road, and was probably worked by a shaft of which the spoil-heap remains, not far south of the cross-roads at Poolfold.

In the stream on the north-west side of the road dark shales with thin beds of gannister have a variable westerly dip of from 5 to 10 degrees, and transgress the strike of the thick sandstone west of Biddulph Mill, being evidently separated from it by another fault with downthrow to the south.

At Bailey's Wood, north of Marsh Green, the Biddulph Brook bends sharply from a northerly to a westerly course, and then, after receiving the tributary stream above-described, swerves abruptly to the north again. Below the main road, in the Biddulph Brook, just before it bends westward, the measures exposed give the following section :—

Character of Strata.	Thickness. FT.	INS.
Hard grey laminated gannister	0	4
Hard grey gritty marl	0	3
Hard grey laminated gannister and sandy shale	0	10
Coal	0	0½
Light grey laminated gannister	0	4
Light grey sandy shale	0	4
Light grey gannister	0	3
Dark grey sandy shale with grit-bands	1	0
Light grey gannister	0	3
Dark grey sandy shale	1	0
Hard white, rather coarser sandstone, seen for	1	6

In the angle of the brook, a few yards further north, shale and sandstone with varying dip lie in proximity to the Spring House Fault. The position of these measures in the sequence is uncertain, but the southerly downthrow of the fault must place them on a horizon considerably above the Crabtree Coal.

In the bend of the stream, where it turns again to the north, a small section shows somewhat higher beds:—

Character of Strata.	Thickness. FT.	INS.
Red Boulder-clay	–	–
Hard black and rusty shale and hard grey marl	5	1
Hard grey claystone	0	8
Hard black shale	–	–

Fragments of coal under the Drift suggest the outcrop of a small seam above the shale.

No rock appears southward in the Biddulph Brook until a point is reached west-south-west of Biddulph Church, where blue shales reach the surface, probably on a horizon not very far below the Winpenny Coal.

East of here, Drift obscures the ground, and the Coal-measures scarcely anywhere reach the surface. The Drift, however, is for the most part thin, though it obliterates the feature of the sandstone below the Little Row Coal. This rock reappears in the driftless ground further south, and runs with a regular outcrop parallel to that of the First Grit west of Outwood Gate and Wickenstones. Near the former a small exposure in a ditch shows the shales between this rock and the First Grit.

A small feature striking south to Woodhouse probably marks the outcrop of the pebbly rock below the Crabtree Coal, seen in the stream to the north. South-east of Woodhouse and immediately north of the road a tip-heap shows the site of an old shaft sunk to the Crabtree Coal at a depth of 70 yards, the measures here dipping west at 20 degrees on the south side of a fault. West of Outwood Gate the outcrop of the Crabtree Seam, displaced eastwards by this fault, is indicated for some distance southward by a series of trial-holes. Within a radial distance of 250 yards from Ox Hay, west, south, and east, old shafts probably went down to the Crabtree, but no information about them could be obtained.

West of Firwood House, at the north end of Wickenstones, three little rills follow the dip down to a small valley which runs north-north-west with the strike before draining into the Biddulph Brook at the north end of The Coppice. In the middle one of these three rills black shale was seen to pass westward under the fine-grained pebbly grit below the Crabtree Coal. Two small watercourses unite in the southern part of The Coppice to form the brook which drains the whole length of that wood,

Near the south end of The Coppice a small trial-hole on the bank of the more easterly of these water-courses shows fragments of coal and shale with badly preserved *Goniatites.* The exact position of this marine horizon is open to some doubt. Evidently the trial-hole was dug to find the Crabtree Coal, but it seems possible that a small seam found here may be slightly higher and may indicate another horizon of marine fossils. The outcrop of the pebbly grit seems to run outside The Coppice on the east, and thence to continue southward. It may be, however, that, with the fall of the ground towards the brook, a low dip keeps the Crabtree near enough to the surface for it to have been found in the trial-hole. The brook shows a fine section of the overlying shales; but, as it follows the strike, the beds exposed are approximately on the same horizon. They have a dip variable in direction and amount, but on the whole westerly.

Higher in the sequence several beds of sandstone cropping out near the disused reservoir of the Bradley Green Waterworks mark the incoming of more sandy conditions at the top of the barren measures. Above the lowest of these sandstones, which ends against a fault at Braddocks Hay, a bed of purple and red marls and flags occurs. A trench recently dug during drainage operations across the strike of the most prominent feature a short distance north-west of the old reservoir showed grey marls on hard grey flags. No indications suggest that the seams between the barren measures and the Winpenny have ever been worked or proved hereabouts.

West of Mow Cop.—As some doubt exists as to the position of the fault (p. 170) which cuts out the lowest beds of the Coal-measures, and as few exposures give any clue to the nature of the strata below the Winpenny Coal, it remains an open question how much of these measures is represented at the surface. On descending the westward slope several sandstones forming small features occur on the same strike as shales to the north which are below the Millstone Grit. Probably the measures down to the Silver Mine or the Cannel Row crop out south of the old mineral tramway from the Tower-hill Colliery. As north of here the features are discontinuous, it may be that another fault with westerly downthrow, though not shown on the map, runs in the direction of Ley Farm.

Close to the lane on the south-west side of Grotto Wood, about 250 yards from the north-west corner of the wood, a small quarry shows a hard fine-grained sandstone with quartz-pebbles. This, if followed along its strike southward, would fall into place not far from the natural position of the Crabtree Coal. In fact, it is probable, though not certain, that this is the pebbly grit below that coal. It gives, however, almost the only tangible evidence for the correlation of the lowest measures on the west side of Mow Cop.

Measures from the Winpenny Coal upwards.

These measures are well exposed in streams on the west side of the Biddulph Valley, but not so well on the east. The Winpenny Coal is practically not worked at all. Exposures of its outcrop show a roof of grey shale, and a floor of grey sandy shale and thin flags with small ironstone-nodules. A short distance above it the Winpenny Rock, a hard bed of sandstone, sometimes partly red, usually makes a feature. Occasionally it is seen to pass up into a bed of light purple micaceous and sandy shale. The following general section of the strata immediately above the Winpenny Coal in the neighbourhood of Hall o'Lea was supplied by Mr. Branson, Manager of the Hall o'Lea Colliery:—

GENERAL SECTION AT HALL O'LEA.

Character of Strata.	Thickness. Ft.	In.
Bullhurst Rock	42	0
BULLHURST COAL	4	6
Measures	15	0
Rock	12	0
Measures	24	0
WINPENNY COAL	3	0

The Bullhurst Rock has a characteristic appearance. When unweathered, it is a hard fine-grained greyish-white sandstone, often blotched and streaked with red, or minutely speckled with purple, and, particularly in the lower part, full of pellets of purple marl, whence its local name of pudding-stone. It contains smuts and streaks of carbonaceous matter, and plant-stems. It frequently makes a conspicuous feature. Above the Bullhurst Rock the measures up to the Whitehurst, Sudden, or Limekiln Coal are light grey sandy marls. On the west side of the Biddulph Valley some 20 feet of white flaggy sandstone above this coal is succeeded by rusty shales, in which a shell-bed or beds several feet thick, crowded with *Carbonicola acuta*, occur not far below the Eight Feet Bambury Coal. The section of No. 2 Shaft of the Moss Pits (see Appendix sect. 36. p. 446) shows these shell-beds as 9 feet thick at a distance of 18 feet below the same coal. This horizon, exposed in several stream-sections on the west side of the Biddulph Valley, would serve as a useful datum for correlation, were there otherwise any difficulty in recognising the Eight Feet Bambury Coal. The rock which underlies this coal further south-west, and is four yards thick at the Bunkers Hill Colliery, Talke, is here either absent or very thin.

Mr. Branson furnishes the following generalised section of the measures from the Eight Feet Bambury up to the Rider Coal above the Four Feet at Hall o'Lea:—

* *Mem. Geol. Surv.*, Iron Ores of Great Britain, Part iv, p. 296.

GENERAL SECTION IN THE NEIGHBOURHOOD OF HALL O'LEA.

Character of Strata.	Thickness. Ft.	Ins.
RIDER COAL -	3	0
Black Shale -	1	0
FOUR FEET COAL	4	0
Marl - - - -	3	0
RAGMAN COAL - - - -	3	0
Measures, with bed of shells, ferns, and other plants at bottom - .	120	0
ROUGH SEVEN FEET COAL	7	0
Measures -	90	0
SMITHY COAL	1	8
Measures - - -	90	0
STONY EIGHT FEET COAL	7	0
Measures - - - -	75	0
Ten Feet Rock, about -	6	0
TEN FEET COAL - - -	? 10	0
Measures, probably - 150 to	240	0
{ TWO ROW OR MAGPIE COAL -	3	0
{ BOTTOMS - - - -	1	6
Dirt - .	3	0
HOLLY LANE COAL - - - -	3	3
Measures with strong rock, about 2 ft. 6 in. thick, a short distance above the underlying coal -	105	0
BOWLING ALLEY COAL - - -	3	6
White pottery marl - - -	3	0
Measures, with hard rock, about 7 feet thick, a short distance above the underlying coal	81	0
JOHNNY GALLEY COAL, in three bands- -	3	0
Measures - - -	78	0
Measures with three small COALS, the lowest resting on the Bambury Rock -	42	0
Bambury Rock - - - - -	4	0
Bass, etc, varying from 2 feet to 14 yards or more ; average	24	0
SEVEN FEET BAMBURY COAL - -	6	0
Measures - -	145	0
Rock - - -	5	0
EIGHT FEET BAMBURY COAL - .	9	0

The above section shows a small rock above the Eight Feet Bambury Coal. In streams on the west side of the Biddulph Valley this rock was not recognised and may have disappeared. Black shale is seen a short distance above the coal, and higher up two small coals are separated by grey shale. The remaining measures up to the Seven Feet Bambury Coal consist of grey shaly and sandy beds. The thick Bambury Rock of the southern district, represented by four feet of sandstone at Hall o'Lea, is perhaps even thinner on the west side of the Biddulph Valley. The above general section shows great variation in the distance of this rock from the coal, and in the southern district there is variation within narrower limits in the thickness of the intervening shale, which sometimes disappears. The marine bed recognised by Mr. Stobbs (page 48) at a horizon not far above the Seven Feet Bambury Coal in the western part of the coalfield has not been found in this northern district.

Above the thin Bambury Rock the measures in the Biddulph Valley seem to be chiefly shales up to the Ironstone Mine Coal; this is perhaps one of the three small coals above the Seven Feet Bambury in the Hall o'Lea general section, in which the Johnny Galley Coal, in three seams, seems to be the Stinking Coal, of the Old Bradley Green Colliery (see Appendix Sect. No. 25). Above the Ironstone Mine eight or nine yards of shale separates that seam from a higher small coal two feet thick, known as the Ragman at the Falls Colliery; this latter is overlain by a bed of shale and ironstone full of well-preserved specimens of *Carbonicola robusta*, with some of *Neuropteris*. Above this horizon thin black and grey shale lies below a coal known as the Bright Coal at the Falls Colliery, 1 ft. 6 in above which a band of ironstone-nodules with occasional *Spirorbis* underlies more grey and black shale. No clear exposures have been recognised of the measures, chiefly shale, which include the Johnny Galley or Stinking Coal. A short distance below the Bowling Alley Seam of Biddulph a thin sandstone occurs, and immediately below the coal at Hall o'Lea a bed of good white pottery marl. The Bowling Alley of the Biddulph Valley is the Hard Mine or Sparrow Butts of the ground further south; while the Bowling Alley of the Potteries is the Magpie or Top Two Row of the northern district.

Green called attention to a marked thinning of the measures, by implication in a westerly direction, and especially conspicuous between the Magpie and Holly Lane Coals, in the shaft-sections of the Towerhill and Bradley Green Collieries*. He did not, however, state from which shafts these sections were taken. Evidently the Towerhill Section (Sect. No. 26, Appendix) does not belong to a shaft of the main colliery at Towerhill, but to that of a pit some distance south-east of it (see footnote, p. 96). Consequently it lies south-west or south-south-west of any possible shaft at the Bradley Green Colliery. A comparison of the section of the New Engine Pit of the Biddulph Valley Coal and Iron Works with the Bradley Green section (Sect. Nos. 27, 25, Appendix) shows, besides some southerly decrease of thickness between the Magpie and Holly Lane Coals, a strong diminution in the same direction between the Holly Lane and the Hard Mine or Bowling Alley. The attenuation of the measures of this part of the sequence, though certainly strongest towards the west, takes place then, in a marked degree, towards the south also. For convenience of comparison the sections at Hall o'Lea, Towerhill, Bradley Green, and the New Engine Pit of the Bid-

***Mem. Geol. Surv.*, Geology of the Country round Stockport, Macclesfield, Congleton, and Leek, pp. 31 and 32. Commenting on the sections, he states that "the thickness of the measures between the Magpie and Winpenny Coals is twice as great at Bradley Green as at Tower Hill"—a statement which is not borne out by the figures in the sections, which give 683 feet 9 inches between these coals at Tower Hill, and 1,009 feet 3 inches at Bradley Green.

dulph Valley Coal and Iron Works, between the Magpie and Bowling Alley or Hard Mine Coals, are here given together.

Character of Strata.	HALL O'LEA. Thickness. ft. in.	TOWER HILL. Thickness. ft. in.	BIDDULPH ENGINE PIT. Thickness. ft. in.	BRADLEY GREEN. Thickness. ft. in.
MAGPIE COAL	4 6	5 0	4 0	5 0
Measures	3 0	5 0	36 0	43 0
HOLLY LANE COAL	3 3	3 0	4 0	4 0
Measures	105 0	100 0	118 7	158 0
BOWLING ALLEY or HARD MINE COAL	3 6	5 0	4 9	6 0

The Towerhill Shaft lies nearly two miles due east of the Hall o'Lea Colliery. The Biddulph Engine Pit is about one mile south-east, and the Bradley Green Colliery little more than half-a-mile north-east of the Towerhill Shaft; the Bradley Green Colliery being about one mile and a quarter north of the Biddulph Engine Pit.

The grey rock above the Hard Mine Coal, upwards of 50 feet thick at the Biddulph Valley Coal and Ironworks, thins out westwards, until at Hall o'Lea a thickness of only 2 feet 6 inches remains. It is the "Bowling Alley Rock" of the Biddulph district.

Mr. Branson states that there is no red rock below the Ten Feet Coal at Hall o'Lea, but a rock six feet thick occurs above it; while at Towerhill there was four feet of red rock above the same coal. Thus the red rock 100 feet thick below the Ten Feet Coal at the Biddulph Valley Ironworks, where it is known as the Ten Feet Rock, though doubtless the thickened representative of the Bowling Alley Rock of the Potteries, has entirely died out westwards; while the thick Ten Feet Rock, often partly red, above the Ten Feet Coal in the southern district, has dwindled to apparently nine feet at the Biddulph Valley Ironworks, to four feet at Towerhill, and six feet at Hall o'Lea.

There are no good sections in the higher measures within this district, and the only information concerning them is afforded by the scanty details of the shaft-sections.

*Nature and Quality of Coals.**

The following are the characteristics of the chief seams in the northern part of the coalfield.

Bradley Green Colliery (Biddulph Valley Coal and Iron Works)†.—All the mines from the Sparrow Butts or Hard Mine upwards have been worked out at the Bradley Green Colliery. The Bullhurst Coal is here too full of sulphur for iron-making. The Winpenny has never been gotten, and is too thin to work at a profit.

* See also Green, *Mem. Geol. Surv.*, Geology of the Country round Stockport, Macclesfield, Congleton, and Leek, page 32.

† Information by Mr. J. H. Cole.

Seam.	Character.
TEN FEET COAL - -	Second-rate manufacturing and steam coal.
MAGPIE COAL	Second-rate house coal.
HOLLY LANE COAL - - -	First-class house-fire coal.
HARD MINE OR SPARROW BUTTS COAL -	Excellent furnace and steam coal.
SEVEN FEET BAMBURY OR FROGGERY COAL	Steam coal.
EIGHT FEET BAMBURY OR NEWPOOL COAL	Furnace or seconds house-fire or steam coal.
BULLHURST COAL	Inferior house and inferior steam coal.
WINPENNY COAL - -	Fair steam coal.

All these coals are open-burning and non-bituminous.

Falls Colliery *—The Ragman (local), Ironstone Mine, and Seven Feet Bambury or Froggery are worked by footrill (inclined shaft). The details of the Froggery Coal are as follows:—

	Thickness. ft.	in.
Good Coal -	3	9
Parting (amount variable) -		6–8
Inferior Coal -	1	6

Hall o' Lea Colliery (Goldendale Iron and Coke Co.) and Neighbourhood. †

Seam.	Character.
LITTLE ROW COAL	Good house coal.
YARD COAL	Not very good coal.
RIDER COAL	Locomotive steam coal.
FOUR FEET COAL	House coal.
RAGMAN COAL	Good house coal.
ROUGH SEVEN FEET COAL	Good steam coal.
SMITHY COAL	Used by blacksmiths, a very good coal for welding.
STONY EIGHT FEET COAL	Very inferior coal.
TEN FEET COAL	Inferior coal.
TWO ROW (MAGPIE) COAL	Good steam coal.
HOLLY LANE COAL	Very good house coal.
BOWLING ALLEY COAL	Not very good coal.
SEVEN FEET BAMBURY COAL	Best house and best gas coal.
EIGHT FEET BAMBURY COAL	Seconds house and gas coal.
BULLHURST COAL	Very good house and gas coal, even better than Seven Feet Bambury.
WINPENNY COAL	Best house and gas coal.
SILVER MINE COAL	Good coal.

Local Details and Sections.—The course of the outcrops will now be traced around the Biddulph Valley from west to east.

* Information by Mr. T. C. Cottrell.
† Information by Mr. C. Branson.

South-east of Mow Cop, and a quarter of a mile west of the disused Towerhill Colliery, the Mow Cop Pit (Sands Colliery) works the Bullhurst Coal from its outcrop The overlying Bullhurst Rock is reddish and has its usual aspect. Two old shafts a little further west were evidently on the Winpenny.

In the clay-pit of an old brickworks further north the outcrops have not been identified, but northward from here a prominent ridge running in approximately the same line of strike but probably displaced a little to the west by a fault with northerly downthrow, exhibits a reddish sandstone with pellets of purple marl, and is evidently the Bullhurst Rock. The outcrop runs north-east to a small stream, in which abundant coal-*débris* attests the Bullhurst Coal beneath the rock. A little further west a bed of white sandstone appears in the same stream with a coal probably the Winpenny, above it. Two or three old trial-pits seem to show the outcrop of the Bullhurst Coal north of this stream as far as another small stream flowing south of Hayhill Farm. A coal seen in the latter stream appears to be the Bullhurst. Another coal, probably the Winpenny, crops out at the south end of the orchard at Hayhill Farm and overlies a thin white fireclay with rootlets, resting on a few feet of flags.

In the main brook west of the road and just below the confluence of the two streams just mentioned a bed full of *Carbonicola* appears in rusty shale, and must be that below the Eight Feet Bambury Coal, the outcrop of which could be traced by a belt of dark coaly soil stretching north-eastward up the slope of a ploughed field. A little lower down the stream, forty yards west of the road to Gillow Heath, thin, hard, white flags show themselves, and traces of the Seven Feet Bambury Coal can be found below.

Another small rill joins the main stream at the road. On returning southward up this rill, a thick coal, evidently the Eight Feet Bambury, appears in the upper part of its course 200 yards north of Towerhill Farm, and its outcrop can be traced for some distance to the north-east. Two other coals crop out lower down in the rill, the more easterly of these being the Seven Feet Bambury, overlain by thin, flaggy sandstone.

A feature at the old Towerhill Colliery continues nearly in the same line north-east, though perhaps intersected by a fault, and passes east of Towerhill Farm, beyond which it becomes stronger. North-east of the farm, a small quarry exposes purplish sandstone containing pellets of purple marl, apparently with a coal under it. The rock must be the thick red rock below the Ten Feet Coal, here attenuated westward, while the coal below is doubtless the Magpie.

Where the road from Mow Cop, running south-east from the farm above-mentioned, branches eastward to Red Cross, an old colliery formerly existed, of which the spoil-heap still remains on the north side of the road. The shaft was sunk on the Rough

Seven Feet Coal close to the surface.* This coal is stated to crop out in the road 200 yards west of the point where the lane diverges to Red Cross. It must evidently bend round in the syncline a very short distance north of the old shaft.

To return northward to the stream mentioned above (p. 95), where the Seven Feet Bambury was described as cropping out west of the road to Gillow Heath; a series of good exposures is seen east of this road as far as the railway. Close to the road the measures below the Bowling Alley Coal crop out up to the sandstone which lies a few feet below that coal; but the Ironstone Mine and neighbouring small coals were not recognised. The Bowling Alley Coal also does not appear, but from the north side of the stream its surface-position, having a regular north-easterly strike, can easily be traced as far as the road by means of a small but abrupt fall in the slope, where the coal has formerly been dug along its outcrop. Indeed, it often happens in this neighbourhood, where the strike of the seams is so regular and no Drift obscures the ground, that a more or less clearly-cut downward step of one or two feet in a slope, or a slight depression on the flat, running in the direction of strike from or near an exposure in a stream, gives with certainty the line of outcrop along which a coal was formerly dug out at the surface.

Between the Bowling Alley and Holly Lane coals the measures do not show in the stream, but the position of outcrop of the Holly Lane and Magpie coals is ascertained, and the course of the former in both directions can be followed at the surface by the indications just described. North of the stream the last two seams mentioned were lately worked by a footrill at Moody Street.† A clear section in the same stream immediately south of the farm known as Moody Street, exhibits the red and purple sandstone and associated purple marl between the Magpie and Ten Feet coals. A slight depression running south-westward is said to mark the outcrop of the Ten Feet Coal above the red sandstone. But this coal must immediately bend round at the surface in the trough of the syncline, for south-south-east of the farm the steep south-easterly dip of the western limb gives place to a slight westerly inclination. The high dip of the western part of the fold, probably averaging about 50 degrees east-south-east at Hayhill, varies, as seen in the stream, especially in the softer beds; but on the whole, when followed eastward, becomes more south-easterly and higher, increasing to 70 or 80 degrees

* This is probably the shaft of which the section (see Sect. No. 26, Appendix, and above) was published by Green as a shaft-section of the Towerhill Colliery, to which this old pit evidently belonged. At the main colliery south of Towerhill Farm, the surface-measures are lower in the sequence

†The Magpie and Holly Lane are said to be here 18 yds. apart, but this is doubtless the horizontal distance between them in the "crut," not the thickness of the intervening measures.

near Moody Street. In the red sandstone below the Ten Feet Coal, due south of the farm, the dip has become nearly or quite vertical in the west side of the trough.

Following the trend of the Ten Feet Seam, the Magpie, Holly Lane, and Bowling Alley coals have all bent round in the trough of the fold and cropped out between the stream south of Moody Street and the one next to the north.

The latter stream, flowing south of the Falls Colliery, affords an incomplete section of the strata from the Winpenny up to the Bright Coal of that colliery. Two rills, uniting near a coppice a quarter of a mile west of the colliery, form this stream. Close to the more southerly of these rills, the Winpenny Coal has lately been opened in a trial-digging at a point 50 yards above the junction of the two. Again, 25 yards below the junction in the north bank of the main stream the same seam, with the overlying rock, was exposed in a trial-hole, as was also the Bullhurst Rock a few yards further east. The Bullhurst Coal, it is stated, was found to be unusually thin.

The following section in the west side of the trough can be made out in this stream, in descending order westward to the outcrop of the Bullhurst Rock. The outcrop of the Bright Coal is 160 yards west of the point where the cart-road to the colliery crosses the stream. The Ironstone Mine crops out at 180 yards west of this point; the Seven Feet Bambury or Froggery at 235 yards, under an oak-tree; and the Eight Feet Bambury or Newpool at 280 yards.

STREAM-SECTION, SOUTH OF THE FALLS COLLIERY, GILLOW HEATH.*

Character of Strata.		Thickness. Ft.	In.
Grey shale			
Band of ironstone-nodules, with occasional *Spirorbis*		0	2
Grey and black shale		1	6
BRIGHT COAL (local)		1	9
Thin carbonaceous shale and grey shaly marl	Perhaps	25	0
[Ironstone-band full of *Carbonicola robusta*, with some *Neuropteris*		0	2]
[Shale		1	0]
RAGMAN COAL (local)	About	2	0
[Measures, probably shale	Perhaps	27	0]
IRONSTONE MINE COAL	About	3	0
Black shale, with hard bands Buff and grey weathered marly and shaly sandstone		170 or 180	0
SEVEN FEET BAMBURY OR FROGGERY COAL	About	[5	6]
Grey and buff marly sandy beds COAL, small Grey shaly marl	About	100	0
COAL		3	0
Hard black shale	About	30	0

* Such parts of the section as are not clearly seen in the stream are filled in according to information obtained from neighbouring collieries or from knowledge gained from other stream sections, and are enclosed in square brackets.

Character of Strata.		Thickness. Ft.	In.
EIGHT FEET BAMBURY or NEWPOOL COAL - -		[9	0]
Shale, with hard bands - - -	Perhaps	25	0
Rusty shale with beds full of *Carbonicola acuta* - Black rusty shale -	About -	[50	0]
White flaggy sandstone -	Perhaps	20	0
WHITEHURST COAL - -	-	?	
Light-grey thick-bedded sandy marl	About -	[60	0]
White sandstone, with pellets of purple marl, and plants (Bullhurst Rock)	About	[40	0]

The dip is high, but variable in amount.

West of Holly Lane Farm, which evidently gives its name to the Holly Lane Coal, the road from Gillow Heath bends abruptly to the south-south-west. 150 yards from it on the west, and a little more than 50 yards south-west of the stream, a "footrill" works the Ironstone Mine and the two-foot seam above it.

At the Falls Colliery, the same method is employed in obtaining the Seven Feet Bambury or Froggery, the Ironstone Mine, and the coal just above it, here known as the Ragman— One foot above this two-foot coal the band of *Carbonicola robusta,* mentioned in the stream section, is stated to occur. The Seven Feet Bambury crops out about 50 yards west of the footrill of the Falls Colliery.

Between the stream south of this colliery and another to the north, the Bright Coal, the Ragman, and the Ironstone Mine crop out in the bend of the syncline.

The northern stream exposes the measures between the Winpenny and Eight Feet Bambury coals, as well as those for some distance below the former. A trial-hole near this stream on its south side shows the Winpenny Coal and Rock near a fence about 200 yards north-west of the house known as "The Falls." On the north side a fault displaces the coal about twelve yards further west. In another trial-pit on the south side of the stream the Bullhurst Coal, under the rock of the same name, was again found to be thin. The stream-section shows grey shaly marl above the Bullhurst Rock, but does not exhibit the Whitehurst Coal. The shell-beds full of *Carbonicola acuta,* not far below the Eight Feet Bambury Coal, appear again in this stream, and the coal itself crops out at the back of The Falls.

The most northerly outcrop of the Eight Feet Bambury is said to be under a cottage on the north side of the road to Astbury, about 160 yards west of the cross-roads at Gillow Heath. In the same road excavations proved the outcrops of the Bullhurst and Winpenny Coals just beyond the Gillow Heath Pottery. There are no indications of the outcrops of these seams northward, in which direction, however, they clearly cannot extend much further. An old shaft 180 yards north-west of the cross-roads evidently went down to the Bullhurst.

In the east limb of the syncline, as exposures are few, the exact surface-position of the coals is for the most part uncertain. About 80 yards east-south-east of the cross-roads at Gillow Heath an old shaft must be on the Bullhurst Coal in the "flats" of the eastern side of the basin. A slight depression in the direction of strike probably denotes the surface-working of the Eight Feet Bambury under thin Drift on this side of the trough at Gillow Heath. The Ironstone Mine crops out about 140 yards east-south-east of the footrill of the Falls Colliery, and was proved in a trial-shaft close to its outcrop. A small coal, probably above the Bright Coal, with a westerly dip of 10 degrees, underlies blue marl covered by thin Drift, close to the axis of the fold in the stream south of the colliery. Near this stream, a few yards west of the railway, an old shaft probably went down to the Eight Feet Bambury. In the stream south of the station, shale and thin flags appear, doubtless belonging to a horizon not far below the last named coal. Grey shales seen in the railway-cutting under Drift-sand north of the Railway Station must lie a little lower in the sequence, but again their exact horizon is uncertain. Old shafts west and south of the station probably went down to the Bullhurst. Mr. Cole states that the houses immediately north of the Police Station at Bradley Green stand upon the site of old shafts to the Winpenny, here close to the surface.

In the stream which flows south of Moody Street, a coal, most likely the Bowling Alley, crops out 100 yards due west of the railway, and grey shales with thin sandstones are seen dipping gently westward as far as the axis of the fold; but no other coals were detected, though the Holly Lane and Magpie should occur in this part of the stream.

It is stated that at the south end of Bradley Green the Winpenny Coal could be seen formerly to crop out in a brick-pit just east of the junction of John Street with the Tunstall Road. The outcrop of the same coal, striking west of north and cutting the road 500 yards east of the cross-roads at Red Cross, was also proved in the grounds of Knypersley Hall.

On the lower part of the western slope of Mow Cop the outcrop of the Winpenny Rock makes a ridge, striking north and south, 200 yards west of Rode Close. An old pit at the south end of this short ridge shows the rock to be in part reddish. The Winpenny Coal has lately been worked under it from the surface by a footrill near the north end of the feature. Almost immediately to the west the Bullhurst rock forms another small eminence. An exposure in this rock shows it to be, as usual, a hard greyish-white rock, with red spots and numerous pellets of red and purple marl. 100 yards further west beyond a small valley, the Eight Feet Bambury has been found at the surface. On the same side of this valley, a little distance to the south, old workings attest the outcrop of the Seven Feet Bambury in apparent continuity with that of the Eight Feet

Bambury, but a fault intervenes. East of this position the outcrops of the Eight Feet Bambury and Bullhurst coals are given on the map on the authority of Mr. Branson, as also those of the Bowling Alley, Two Row, Ten Feet, Stony Eight Feet, Rough Seven Feet and Four Feet Coals in succession above the Seven Feet Bambury to the West. The abnormally close proximity of the Stony Eight Feet, Rough Seven Feet, and Four Feet to each other bears witness to a supposed upward bending of the lower two of these seams, and a consequent squeezing of the strata between them and the Four Feet Coal.

Such of the coals as are repeated still further west by the 280-yards fault at the Hall o' Lea Colliery (p. 171) have not been recognized at the surface.

POSITION OF SEAMS IN SHAFTS.

So far only the outcrops of the seams and measures have been traced. Some details will now be given of the proved position of coals in the colliery shafts.

At the Hall o' Lea Colliery west of Mow Cop, in the shaft on the south-west side of the stream, the Seven Feet Bambury Coal lies at a depth of 160 yards, on the upcast side of the 280-yards fault.

At Red Cross, the shaft of an old colliery 200 yards east of the cross-roads, and immediately south of the road running eastward, was sunk to the Bullhurst Seam at a depth of about 45 yards. Another old shaft 100 yards north-east of the church at Red Cross went down to the Winpenny. A third, 60 yards west-south-west of the bridge over the railway, is on the Seven Feet Bambury Coal.

In No. 5. shaft of the Bradley Green Colliery, the Newpool lies at a depth of 237 yards. In No. 6 shaft, 65 yards further west, the Bowling Alley is 90 yards deep. In a shaft by the side of the lane from Bradley Green to the colliery, at a point 50 yards east of the railway, the Bullhurst, dipping west at 30 degrees, is at a depth of 173 yards. No. 3 shaft reached the Winpenny Coal 170 yards due west of the Tunstall Road. An old shaft on a tip-heap by the roadside 250 yards south-west of Holly Lane Farm reaches the Seven Feet Bambury Coal, at a depth of 150 yards, the Newpool Seam, 35 yards further east, being 200 yards from the surface.

Mr. Cottrell, of The Falls, states that at a point 150 yards east-south-east of the house the Newpool Coal was proved at a depth of 92 yards, dipping south-west.

At the Gillow Heath Pottery, the Bullhurst Coal, with a dip of 27 degrees east-south-east, lies 20 yards below the mouth of the "crut" by which the pottery-marls are reached.

WESTERN ANTICLINAL REGION.

For purposes of description this region can be divided into geographical sub-sections.

Madeley-Leycett Section.

(By W. GIBSON.)

Throughout this section of the anticline the information obtainable is of a very imperfect character, owing to the absence of natural exposures and details of shaft sections.

Eastern side.—In the Silverdale district owing to the varying inclination of the strata direct measurements are difficult to obtain. The chief seams worked lie towards the lower portion of the sequence. They include both gas and house coals. The lowest seam is the Bullhurst Coal, which is met with at a depth of 166 yards in the Crackley Pits and 430 yards in the Sherriffe Pits. The other seams chiefly worked are those between the Bullhurst Coal and Four Feet Coal. Work on the ironstones was somewhat extensive in the past, and the Chalky Mine Ironstone and Gold Mine Ironstone, which is 218 yards deep in the Hollywood Pit, were also raised, but are now neglected for the richer and more easily worked Black Band Ironstones.

The breadth of outcrop of the beds is much restricted, owing to the high inclination of the measures and from their being crossed by the Hollywood and Anticlinal faults (pp. 174, 175).

The angle of inclination of the seams varies considerably. Close to the summit of the anticline the Bullhurst Coal is found in the Crackley Pits to dip at an angle of 10 degrees to the south-east. This dip has increased to 54 degrees about 300 yards to the south-south-east. After this the measures slowly flatten, till about 900 yards to the south-east of the Crackley Pits, the Great Row Coal dips to the south-east at 36 degrees; and below the Market Drayton Line of the North Staffordshire Railway, at Hollywood, the dip in the same coal, which is 300 yards below the surface, is further diminished to 23 degrees.

The shafts are all situated on the eastern side of the anticline, that is to say they are on the "Staffordshire Dip." The axis is crossed at a depth of 166 yards in the Eight Feet Bambury Coal below the disused mineral line to the north of the Crackley Pits, and emerges in the railway cutting a few yards to the west of the road leading to Scot Hay.

This cutting affords by far the best sections in the neighbourhood, and shows more or less of the sequence between the Ten Feet Coal and Great Row Coal. The measures above the Ten Feet Coal, situated close to and on the eastern side of the anticlinal axis, crop out in the cutting to the south of the road leading to Scot Hay. The lowest beds consist of dark grey shales with lenticular bands of grit, succeeded by black shales with bands and nodules of calcareous ironstones. Plant remains are very numerous and in an excellent state of preservation. The cutting is much grassed, but a small stream, flowing parallel with the north

side of the railway, continues the section in grey and black shales with a seam of coal, of which a thickness of over two feet is visible. The Great Row Coal is said to crop out close to the foot-bridge, north of the Silverdale Ironworks. This portion of the section consists mainly of black shales containing a few uncrushed specimens of *Anthracomya Phillipsi* and also thin bands of ironstone yielding *Spirorbis* and Entomostraca.

The eastern collieries of the Apedale Coal, Coke and Iron Company work the lower seams between the Bullhurst Coal and Four Feet Coal. The coals are classed as steam, house and coking. The Ten Feet Coal, Seven Feet Bambury Coal, Eight Feet Bambury Coal and Bullhurst Coal are all coking seams The Four Feet Coal is a firsts house coal.

In the Watermills Pits the Ragmine Coal lies at a depth of 121 yards, the Ten Feet Coal at 195 yards, the Seven Feet Coal at 320 yards. In the Burley Pit the Eight Feet Bambury Coal is 465 yards from the surface.

The large Apedale Fault (p. 165) limits the workings to the east, the seams flattening out as the fault is approached. From 25 degrees in the Marl Pit, south of the Apedale Iron Works, the angle increases to 45 degrees to the south-east of Burley Farm, but decreases to 19 degrees under Apedale Hall on approaching the anticlinal axis.

The Four Feet Seam crops out a few yards to the west of the Watermills Pits and the Ten Feet Seam under Apedale Hall. The fragments of rock scattered about the surface to the south of Apedale Hall alone indicate the position of the Ten Feet Rock. A coal visible in a gutter in a coppice to the east of the water tanks, which are situated close to the anticlinal axis, and on the south side of the road from Apedale Hall to Alsager Bank, was pointed out to us by Mr. Weston, who regards it as the Bullhurst Coal. A quarry in orange-coloured sandstone to the south shows a nearly horizontal dip, and is evidently close to, if not absolutely on, the summit of the anticline.

Poor sections of the strata above the Four Feet Coal can be seen in the wooded gully south of the Watermills Pits.

Of the measures near the summit of the series the old marl pit to the south of the Apedale Iron Works affords the following sequence:—

BRICK PITS, 200 YARDS SOUTH OF THE APEDALE IRON WORKS.

Character of Strata.	Thickness. Ft.	In.
Grey shales	4	0
COAL	1	6
Fireclay	3	0
Shales	10	0
Black shales passing down into Black Band Ironstone	8	0
COAL—probably the Bassey Mine of the Potteries	2	6
Coal shales	3	0
Grey marls with nodules of siderite	20	0
COAL ? Little Row Coal	1	0
Grey shales	8	0
Thin coal and shale	5	0

Western side.—The collieries situated on the west side of the anticline work the same seams as those on the eastern side. They are said to be on the " Cheshire Dip."

The most southerly workings are those of the Madeley and Leycett Collieries (Section III., No. 37 Appendix), which obtain the lower seams from the Bullhurst Coal up to the Four Feet Coal. The seams from the Ten Feet downwards, including the Seven Feet Bambury, Eight Feet Bambury (Cockshead), and Bullhurst are house and gas coals, the Four Feet, Single, Five Feet and Seven Feet being house coals, while the Ragman Coal, Five Feet and Hams coals, are described as high-class steam coals. Shallow shafts and open workings in the higher seams lie scattered over the surface. Gibson's Shaft, on the north or upthrow side of the Hollywood Fault (p. 174), is stated to have reached the Brown Mine at 36 yards. The Chalky Mine Coal is said to crop out a little further to the west. So much uncertainty, however, exists about the naming of the upper seams and their correlation with those in the eastern area that little advantage would result from going into detail about them, especially as they occur in a region of much complexity, which is as yet not fully understood.

There are few surface exposures. The rock associated with the Five Feet Coal has been quarried by the roadside north of Leycett Station. When met with underground the rock is intensely hard, the quartz grains possessing such sharp edges that they are stated to cut glass like a diamond. In the cutting of the Audley railway through Hayes Wood, some red sandstone (coloured Permian on the old map), dipping westward off the anticline and much disturbed, occupies a doubtful position in the sequence. It is certainly not Permian or any part of the Keele Group, but constitutes an upper portion of the Grey Chief Coal-bearing Series.

To continue the description northward, in No. 2 Shaft of the Apedale Company, the Ragman Coal, Rough Seven Feet Coal and the Five Feet or Hams Coal, which are twenty yards apart at Apedale, are very close together, near the top of the shafts, and are worked as " rearers." The inclination of the seams varies according to depth. In the higher parts of the workings they are steeply inclined (rearers), but flatten out rapidly on the lower levels. The Minnie Shaft, sunk within the belt of disturbed ground along the " Western Boundary Faults" (p. 175), intersects the Four Feet Coal at 329 yards, and the Five Feet Coal at 336 yards. No attempt has been made to prove the ground to the west of the boundary fault by driving out westward from these pits.

The Seven Feet Coal and the Ten Feet Coal crop out a few yards to the west of the Methodist Chapel, Halmer End. Gas from the underground workings is occasionally set free at the surface.

Exposures for ascertaining the structure of this section of the anticline are practically limited to outcrops of the Bullhurst

Rock in the mineral line north of Miry Wood and in an old quarry at Wood Lane north of the Methodist Chapel. In conjunction with the Seven Feet rock this rock forms the steep slopes between Alsager Bank and Miry Wood. The mineral line from No. 2 shaft intersects a red rock very similar to that in the railway cutting at Hayes Wood, but there are no data by which the horizon can be obtained. Crop-workings in the highly inclined seams about the horizon of the Four Feet Coal occur to the south of No. 2 shaft, on the north or upthrow side of the 72 yards Fault. Remains of shallow open workings exist on the steep hillsides to the east of Miles Green.

The Audley-Harecastle Section.

(By C. B. WEDD.)

North of Miles Green, Wood Lane and Chesterton, the Grey Series occupies a broad area between the higher Coal-measures in the south-east and south-west, and the Trias on the north-west, and thus includes the whole course of the anticline throughout this district. The important lower group of coals from the Bullhurst up to the Ten Feet is mainly obtained along the anticlinal uplift. The middle group of the chief coal-bearing measures is, or has been, worked on both sides of the anticline in the neighbourhood of Audley, Red Street and Harecastle; the highest group, with the Great Row Coal, only on the east side of the anticline. The accompanying diagram shows the relative position of the seams below the Ten Feet Coal in the shafts of the several collieries.

A comparison of the shaft-sections (Appendix III., Nos. 28-35) shows a decided uniformity in the lower part of the series throughout the district, at any rate up to the Stony Eight Feet Coal. Thus, besides the more important coals and the thicker sandstones, which can be traced without difficulty from one colliery to another, the smaller coal-seams and rocks are for the most part persistent throughout the district.

Two pairs of thin coals lie between the Eight Feet Bambury and Bullhurst Coals in No. 1 shaft, Talk o'th' Hill Colliery and the Slappenfield Pit; while at the Diglake Pits a single coal, two feet thick, occurs 62 feet above the Bullhurst Coal (diagram p. 105). A thin sandstone occupies about the same relative position between the two pairs of thin coals at Talk o' th' Hill and Slappenfield. The four-inch coal (Kidney Coal of Talk o'th' Hill) below the Seven Feet Bambury Coal is overlain in the Rookery and No. 1 Talk o'th' Hill shafts by a thin band of ironstone. Between this and the Seven Feet Bambury Coal are two sandstones. Thin sandstones and rock binds, without the coal, occur at about the same horizon in No. 5 shaft, Talk o' th' Hill, and are represented by one thin bed at Slappenfield. The group of thin coals from about 70 to 90 feet above the Seven Feet Bambury Coal is recorded from all the shafts except those of the Rookery Pits of Jamage (see diagram). A third group of

small coals occurs below the Bottom Two Row Coal. The thickest of the group is probably the attenuated representa-

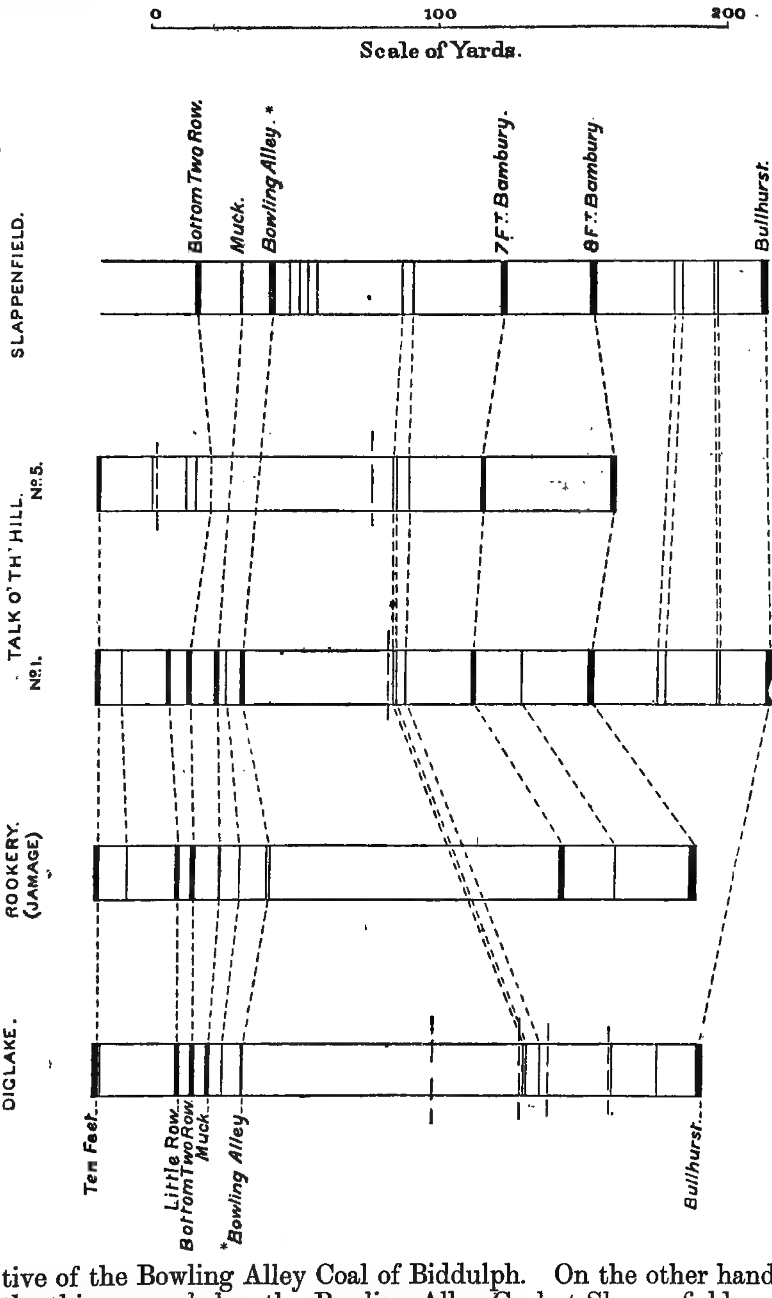


FIG. 10.—COMPARATIVE SECTION OF THE COAL SEAMS BELOW THE TEN FEET COAL IN THE TALKE AREA.—BY C. B. WEDD.

Horizontal broken lines drawn across the sections indicate faults.
* of Biddulph.

tive of the Bowling Alley Coal of Biddulph. On the other hand the thin seams below the Bowling Alley Coal at Slappenfield are not recognised in the other shaft-sections.

The most important sandstones or rocks lie below the Eight Feet Bambury Coal; immediately above the Seven Feet Bambury Coal (Seven Feet or Bambury Rock); a few yards above the Little Row Coal (Two Row Rock); and a few feet above the Ten Feet Coal (Ten Feet Rock).

The Ten Feet Rock in this district is always separated from the coal below by from eight to fifteen feet of shale, except, according to Mr. R. R. Makepeace, in the old shaft of the Rookery Pits at Jamage, where, on one side of a fault, the shale must have been squeezed out, as it is present on the other side.

From the Stony Eight Feet upwards the uniformity is perhaps less marked; moreover, there are fewer facilities for comparison.

Higher measures are illustrated by the shaft-section of the Bath or Harecastle Pits (Section, No. 30. Appendix III), and by the Diamond Drill Borehole of the Talk o' th' Hill Colliery (Sect.: No. 33. Appendix III).

According to the record of the Diamond Drill Boring a coal 5 feet 3 inches thick, known as the Bee Coal, was reached at a depth of 187 feet, and another named the Birchenwood, 4 feet 7 inches thick, at 377 feet, making 190 feet of strata between these two coals. This does not agree very well with the distance between the coals of the same name, or with their thickness, in the Bath Pit two-thirds of a mile distant, where the Bee Coal is only 1 foot 9 inches thick, while the Birchenwood is 5 feet 3 inches thick, and the distance between them 241 feet.

In the opinion of Mr. MacGowan, the Birchenwood ot the Kidsgrove district is probably the same as the Mossfield Coal elsewhere, and certainly the same as the Four Feet Coal of the Audley district, the Four Feet Coal of Kidsgrove being the Five Feet of Audley.

The character of the lower part of the series is illustrated by the shaft-sections given in Appendix III, Nos. 31, 35, 36.

There is little information to be obtained about the highest group in which the Great Row Coal alone is of much importance.

The following data show the nature and thickness of the important seams.

Nature, Quality and Thickness of the Chief Coals at the Different Collieries.

*(Diglake and Boyles Hall Pits, Audley Colliery.)**

These pits now work the Hams, Ten Feet, and Two Row coals: formerly the Bullhurst, Eight Feet Bambury and Seven Feet Bambury, and also the Birchenwood and higher coals.

* Information by Mr. F. Rigby.

Seam.	Character.	Roof and Floor
SEVEN FEET BAMBURY COAL	Best house and gas coal; the best in the district.	
EIGHT FEET BAMBURY COAL	Steam and seconds house coal.	
BULLHURST COAL.	Middle, best house and gas coal; top and bottom inferior.	Roof, grey metal. Floor, warrant.

*(Jamagė and Rookery Pits, Bignall Hill Colliery.)**

Seam.	Thickness. FT. IN.	Character.	Roof and Floor.
SEVEN FEET BAMBURY COAL (with 3 inch band of dirt in middle.)	6 6 to 7 0	Best house coal.	Roof, rock, 60 feet; floor, marl, 5 feet.
EIGHT FEET BAMBURY COAL	7 6	All clean coal; seconds house coal.	Roof, shale; floor, hard.
BULLHURST COAL	9 5	Good seconds coal; Big Tops inferior.	

The Bullhurst Seam consists of the following divisions:—

Character of Seam.	Thickness. FT.	IN.
Big Tops	2	0
Floor	–	–
Little Tops	1	0
Dirt -	0	8
Middle Coal - -	2	9
Bottom or Wall Coal - -	3	0

(Talk o' th' Hill Colliery.)†

Seam.	Thickness. FT. IN.	Character.	Roof and Floor.
ROUGH SEVEN FEET COAL (with 1-inch clay band)	8 1	Steam common coal.	Roof, black bass; floor, warrant.
STONY EIGHT FEET COAL	3 0	Steam common coal.	Roof, white earth, 2 ft., below thick dark metal; floor, brown stone, 8 in., above warrant.
TEN FEET COAL (with thin partings)	9 6	Highly bituminous coking coal.	Roof, metal, 15 ft. under thick rock; floor, grey warrant.
LITTLE ROW (TOP TWO ROW) COAL	1 3		Roof, blue metal; floor, black bass.
TWO ROW COAL	3 7	Open house coal.	Roof, bass; floor, warrant.
SEVEN FEET BAMBURY COAL	7 10	Highly bituminous coking coal.	Roof, thick rock; floor, warrant.
EIGHT FEET BAMBURY COAL	8 4 to 8 9	Highly bituminous coking coal.	Roof, black shale; floor, grey metal.
BULLHURST COAL		Highly bituminous coking coal.	Roof, grey shale; floor, hard white sandstone.

* Information by Mr. R. R. Makepeace.
† Information by Mr. A. M. Henshaw.

The Bullhurst Coal consists of the following divisions :—

	Thickness. Ft.	Ft.
Top Coal	2	0
Clay or hussle		6
Main Coal (good clean coal)	5	0
Two one-inch bands of black sandy shale		2
Floor Coal	2	0

(*Bunker's Hill Colliery.*)*

Seam.	*Thickness.* Ft. In.	*Character.*	*Roof and Floor.*
Seven Feet Bambury Coal	7 6	Best house and gas coal.	Roof, rock, 19 to 21 yards.
Eight Feet, Bambury Coal	7 6	Steam & seconds house coal.	Floor, strong rock, 4 yards.
Bullhurst Coal (including partings and tops)	9 0	Best house and gas (middle part only).	

(*Lawton and Harecastle Collieries and neighbourhood.*)†

These collieries are no longer working.

Seam.	*Thickness.* Ft. In.	*Roof and Floor.*
Birchenwood Coal	5 0 to 6 6 (exceptionally)	Roof, dark shaly metal, 3 feet; floor, rock, 2 feet.
Little Row Coal	2 9	Roof, metal; floor, very hard metal.
Yard Coal (with thin parting)	3 2	Roof, black bass, 1 ft. 6 in.; floor, soft shale, 1 ft. 4 in. on fireclay.
Rider Coal	2 6	
Four Feet Coal	4 6	Roof, clod, 5 ft., on soft black shale; floor, strong fireclay.
Ragman Coal	2 6	Roof, slag and shale; floor, dark shale.
Rough Seven Feet Coal	6 0	Roof, blue marl with ironstone-bands, 6 ft.; floor, saggar clay, 8 ft.
Stony Eight Feet Coal consisting of :—		Roof, dark metal.
Coal	3 0	
Stone parting	0 3	
Slaggy Coal	1 4	
Ten Feet Coal, consisting of :—		Roof, blue metal, 9 ft., under rock, 75 ft.; floor, fireclay, 8 ft.
Main Coal	7 4 to 8 4	
Billy Coal	1 0	

* Information by Mr. F. Rigby.
† Information by Mr. J. MacGowan, Sen.

Seam.	*Thickness.* Ft. In.	*Roof and Floor.*
Yard Coal, about	2 9	Roof, strong dark metal, with iron stone bands, 2 ft.; floor, strong fireclay, 3 ft. 6 in.
Top Two Row Coal	3 0	Roof, strong grey metal, 3 ft. 6 in. floor, rock, 7 ft.
Under Two Row Coal	2 0	Roof, dark metal with ironstone-bands, 3 ft. 6 in.; floor, strong fireclay, 3 ft.
Muck Coal	–	
Bowling Alley Coal (at Moss Pits) consisting of :—		Roof, blue metal, 6 ft, under rock, 16 ft.; floor, warrant 3 ft.
Coal - -	2 11	
Dirt - - - - -	0 3	
Coal -	0 8	
Seven Feet Bambury Coal	7 0	Roof, sandstone, 81 ft.; floor, shaly warrant, 1 ft. 6 in., on fireclay, 9 ft.
Eight Feet Bambury Coal (at Moss Pits).	7 0	Roof, strong dark metal, 8 ft.; floor, rock.
Bullhurst Coal - (at Moss Pits).	7 0	Roof, dark metal with coal pipes, 6 ft.; floor, rock, 4 ft.

Local Details and Exposures.—The eastern tract will be described first from south to north. The most southerly part of the district east of the anticline affords scarcely any exposures. At the Glasshouse Colliery (no longer working) the Great Row Coal on the downthrow side of the Apedale Fault is 9½ yards from the surface in No. 2 shaft. The outcrop of the Great Row Coal on the map is taken from plans of the High Carr Colliery. A broad zone, mainly of black shales, occupies the surface for some distance north-west of this outcrop. Shales appear in Dean's Lane and in numerous trial-pits north-east of Red Street. Close to the branching of the two roads to Talke, north of Red Street, a section was recently exposed in the roadside opposite the Wesleyan Chapel, but is now built up. It exhibited the following strata in descending order:—

Section in roadside, Red Street.

Character of Strata.	Thickness. Ft. In.
Marl - - - - -	1 0
Yellow grit - - - - -	0 8
Reddish marl - - - - -	0 5
Yellow grit - - - - -	0 2
Yellow marl - - - - -	0 1
Hard grey sandstone - - -	0 7
Grey shale - - - - - - -	0 2
Thin-bedded yellow sandstone - - - - - - -	1 0
Dark grey shale - - - - - - 3 inches to	0 7

Character of Strata.	Thickness. Ft.	In.
Nodular ironstone-bands - -	9 inches to 1	6
Black, grey and brown shaly marl with ironstone-nodules	7	0
Shaly marl, with ironstone-nodules (fossils)	2 to 3	0
Yellow sandstone with ironstone-nodules	1	4
Brown and grey shaly marl, with small ironstone-nodules	3	0
COAL - - - About	3	0
Grey and yellow clay	2	6

The coal, according to Mr. Sumnell of the High Carr Colliery, is the Chalky Mine.

The Bassey Mine Coal is seen in the deep cutting of the Jamage Mineral line north of the High Carr Fault about 50 yards west of the main road to Newcastle. At least four coals can be detected below the Bassey Mine, but their correlation and thickness remain uncertain.

The cutting repeats the same series a little further to the east.

The Great Row Coal is stated by Mr. Sumnell to be at little depth in a shaft situated in the triangle formed by the Jamage line, the Newcastle road, and the lane from Red Street. It is now worked at the High Carr Colliery alone in this district, though formerly obtained at Glasshouse.

At the Bath or Harecastle Pit of the Birchenwood Colliery the New Mine Ironstone is found at a depth of about 25 yards (Sect. No. 30, Appendix III). The steep slope of Harecastle Wood exposes the measures on the west side of the colliery, but a considerable amount of slipping has taken place, so that Glacial sand may here and there be found under Coal-measures. The hill at Harecastle clump has a capping of sandstone which dips south-east, as has also another hill lying south-west of Harecastle Farm. The latter rock is believed to be that above the Winghay Coal.

Further north the Ten Feet Coal was worked in the anticline by a level course from the Lawton and Harecastle Colliery running under Hollinswood at a depth of 132 yards. The Rough Seven Feet Coal is stated to crop out immediately west of the summit of the anticline at No. 15 shaft, east of Hollinswood Farm.

North of Harecastle Station the Ten Feet Rock is exposed in the cutting of the North Staffordshire Railway where the mineral line to the Moss Pit diverges.

In the south, west of the Apedale Fault, under the west flank of the anticline of Bound Hill, the Eight Feet Bambury Coal is worked by a level course from the Diglake Pits of the Audley Colliery, at a depth of 160 yards at the shaft, the dip being 75 degrees west-north-west. A sandstone seen high up on the west flank of the hill is probably the Seven Feet Bambury Rock. A coal exposed in the railway-cutting at the Boyles Hall Pit is stated by Mr. Maddock, the manager, to be the Ten Feet Rider (Stony Eight Feet) Coal which lies just above the Ten Feet Rock.

Consequently, the rock in the lower slope of the northern part of Bound Hill must be that rock.

At the Boyles Hall Pit, where the coals, worked as "rearers" at a high inclination under the flank of Bound Hill, have flattened out westward, the Ten Feet Coal lies at a depth of about 90 yards before it is let down by a fault on the north-west. Beyond the fault the Birchenwood Coal occurs at a depth of about 141 yards under Boyles Hall, and is then cut off by another fault (p. 177), which brings the Etruria Marls to the surface. The ground between the faults is said to be much disturbed.

At the Diglake Pits, the curving fault which crosses the anticline, cuts out the Bambury coals in the shafts, and the Bullhurst Coal is raised to 211 yards from the surface.

At the Bottom (western) Pit of the Bignall Hill Colliery, the Seven Feet Bambury Coal occurs, according to Mr. E. Gater, at a depth of about 40 yards with a north-westerly dip of about 17 degrees. About half-way between the Bottom and Top (eastern) Pits and a few yards to the south, a quarry shows the following sequence in descending order:—

SECTION IN OLD QUARRY SOUTH OF BIGNALL HILL COLLIERY.

Character of Strata.	Thickness. FT.	IN.
Sandstone, with marl-partings and concretionary ironstones - - - -	13	0
Grey marly parting - - - 2 inches to	0	10
Massive, white, fine-grained sandstone	6	0
Grey marl - -	0	4
COAL (SEVEN FEET BAMBURY COAL), bottom not seen	5	6

The inclination is at a low angle to the west, the strata being evidently close to the summit of the anticline. It will be seen that here, as elsewhere in this district, the Bambury Rock lies practically on the coal. A short distance further east, at the Top Pit, the Seven Feet Bambury Coal was worked at a depth of 51 yards, the Eight Feet Bambury at 91 yards, and the Bullhurst at 151 yards, where the beds must have turned over eastward in the anticline. Further east, but still on the upthrow side of the Apedale Fault, the Bullhurst Seam was proved at a depth of 480 yards under Roggin Row, in the workings of the Glasshouse Colliery.

A rock seen in an old quarry near the hill-top, about 150 yards north of the Top Pit, Bignall Hill, is doubtless the Seven Feet Bambury Rock, which appears to remain at or near the surface on the crest of the anticline as far north as Wedgwood's Monument on Old Hill. A few yards north of the monument a slight depression in the crest of the hill marks the outcrop of shale, while immediately to the north the Ten Feet Rock makes a slight feature, just below which the Ten Feet Coal crops out on the west flank of the hill. The base of the Ten Feet Rock crosses the anticline with a V-shaped outcrop, the angle of the V pointing

to the north. As this part of the anticline appears to pitch down northward, in which direction the altitude of the ridge also diminishes, the Ten Feet Rock remains at the surface for a considerable distance. It is exposed in two old quarries on the top of the hill near Old Hill Wood and in another in the north-west corner of the wood; also in a quarry on the northern part of the ridge, west of the Jamage Colliery. In this quarry it is stated that the Ten Feet Coal was proved in a small excavation, below the rock. In its general aspect the Ten Feet Rock is a fine-grained buff, or whitish, somewhat marly sandstone. A red bed occurs near the base, and can be seen in the path by Old Hill Wood.

North of Old Hill, after the anticline has bent round westward, the same rock is well exposed in the railway cutting where the Jamage (Mineral) Line leaves the Audley Branch. The dip is south-south-west, and above the rock to the south the Stony Eight Feet (Ten Feet Rider) Coal is seen, its floor of hard rubbly marl with rootlets showing prominently from top to bottom of the cutting. Above the coal the beds seen are mainly shales and marls with bands of ironstone-nodules.

The Seven Feet and Eight Feet Bambury coals and the Bullhurst are worked as "rearers" in the Rookery and Jamage pits, on the eastern limb of the anticline. The seams are inclined at 70 degrees, but flatten out before reaching the Millstone Fault.

Mining operations are now being carried on east of the fault, and coals in descending order, respectively, 5 ft. 6 in.; 1 ft.; 4 ft; 4 ft. 6 in. in thickness have been met with within a vertical thickness of not much more than 100 feet. It has not, however, been found possible to identify them. They probably belong to a considerably higher horizon than the Bambury Coals.

In driving a "crut" from the Bullhurst level at a depth of about 270 yards, the following measures were passed through in descending order, the thicknesses being corrected for an inclination of 50 degrees.

CRUT FROM THE BULLHURST LEVEL, JAMAGE PITS.

Character of Strata.		Thickness. Ft.	In.
BULLHURST COAL		9	11*
Fireclay	About	2	3
Bass		3	0
Rock		12	3
Bass		8	9
WINPENNY COAL		1	0
Bass	About	20	0
Rock		17	0
Bass		3	0
Rock		17	6
Bass		23	9
COAL		0	7
Bass		22	0
COAL		1	4
Bass		14	6
Rock		5	9

* In Rookery Shafts.

The Eight Feet Bambury Coal is worked from the same colliery at a depth of 300 yards under the middle part ot Parrot's Drumble. It is cut off northward by a fault.

North of the stream which flows through Parrot's Drumble a sandstone is exposed in the roadside south of Windy Arbour. This evidently belongs to the thick series of sandstones, nearly 50 feet above the Bee Coal, met with in the Diamond Drill Boring 400 yards to the north-west (Appendix III., Sect. No. 33).

The Ten Feet Coal in No. 5 Shaft of the Talk o' th' Hill Colliery, about a quarter of a mile east of New Springs, is at a depth of 29 yards approximately, the Ten Feet Rock just reaching the surface in the rising ground. The shaft traverses more than one fault, and the Two Row Coal is cut out by these faults.

A sandstone of some thickness is seen in the road at Talke, near St. Martin's Church. Its exact position in the series is not certain. It is not the Ten Feet Rock, which reaches the surface a short distance further north, with a south-easterly dip; for it must be on the downthrow side of the Millstone Fault, whereas, according to Mr. Henshaw, the Ten Feet Coal is worked at a depth of 90 yards under the church, on the upcast side of the fault. A short distance further south the fault has a throw of 56 yards, but it diminishes northward. The rock should therefore be between 140 and 145 yards above the Ten Feet Coal, and would appear to correspond in position with a rock, 15 feet thick, 143 yards above the Ten Feet Coal in the shaft-sections of the Talk o' th' Hill Colliery.

The Ten Feet Rock comes to the surface in the high ground of Coalpit Hill, and has been quarried on the south-east side of the hill. The Stony Eight Feet Coal crops out above the rock, while the outcrop of the Ten Feet Coal has been proved a little further to the north-west.

At the Bunkers Hill Colliery the Little Row (Top Two Row) Coal lies at or close to the surface from the eastern (Nos. 1 and 2) shafts to a distance of nearly 500 yards south-west of the western (Nos. 3 and 4) shafts, the measures being repeatedly brought up on the west by many small faults. The Bullhurst Coal is also at almost the same level at the extremities of a line joining these points. The Bottom Two Row Coal crops out in the lane leading to Alsager, 400 yards south-west of the western shafts, and again about 150 yards east of the eastern shafts, near the road to Talke. The Ten Feet Coal is at the surface about 130 yards south-west of the western shafts. The Little Row Coal lies at a depth of about eight yards in the western shafts. The thickness of measures between the Ten Feet Coal and the Little Row Coal is about 22 yards; between the Little Row and the Bottom Two Row Coal about 16 yards; between the Bottom Two Row and the Seven Feet Bambury Seam about 110 yards; between the Seven Feet Bambury and Eight Feet Bambury coals about 40 yards;

between the Eight Feet Bambury and the Bullhurst about 45 yards.

The low ground of the neighbourhood of Hollins, Butt Lane and Harecastle Station is almost entirely drift-covered. Mr. MacGowan states that the Birchenwood Coal was proved at the mouth of the Lunts Pit of the Lawton and Harecastle Colliery; the Four Feet Coal about 250 yards further north, between the Weel and Meadow Pits, and the Rough Seven Feet about 70 yards further north, and just south of the Woodshutts Shaft. The measures here have a general southerly inclination (see sect. 13, p. 179). At the Bye Pit the depths to the coals from the surface are roughly:— 30 yards to the Four Feet Coal; 32 yards to the Ragman Coal; 60 yards to the Rough Seven Feet Coal; 90 yards to the Stony Eight Feet Coal and 120 yards to the Ten Feet.

In No. 6 Shaft, Birchenwood Colliery, the Yard Coal is at a depth of 80 yards, the Bowling Alley Coal at 95 yards, the Seven Feet Bambury Coal at 195 yards, the Eight Feet Bambury Coal at 225 yards, the Bullhurst Coal at 280 yards, the Winpenny Coal at 300 yards, the Silver Mine Coal at 343 yards.

In No. 4 Shaft, Birchenwood Colliery, the Birchenwood Coal is at a depth of 20 yards, the Four Feet Coal at a depth of 85 yards, the Rough Seven Feet Coal at 111 yards, the Stony Eight Feet Coal at 150, the Ten Feet Coal at 192, the Two Row Coal at 235 yards, the Yard Coal at 260 yards.

The Ten Feet Rock has been quarried by the roadside south of the Rolling Mill. The rock above the Eight Feet Bambury Coal (Cockshead Coal) forms a couspicuous ridge from the north end of Kidsgrove to near Brewhouse Bank. Several old levels indicate the position of the underlying coal. A level on the Bullhurst Coal in a field to the north of the Mortuary Chapel proved that the seam pinched out when followed on the dip. The Winpenny Coal is stated to crop out on Cobb Moor.

The sections just mentioned are all situated on the upthrow side of the chief dislocation of the district known as the Oldcote Fault (p. 163). On the downthrow side the rock above the Eight Feet Bambury Coal crops out to the north-west of Trubshaw, giving rise to a ridge which extends in a north-easterly direction for a considerable distance. A quarry on the east side of the mineral line from Black Bull, and at a distance of about 350 yards of its junction with the Loop Line, exposes some 10 feet of yellow shales resting on a grey sandstone 30 feet thick. This is underlain by black shales resting on a coal 3 feet 9 inches thick.

CHAPTER VI

CARBONIFEROUS ROCKS—(*continued*).

COAL-MEASURES—(Detailed Description, *cont.*).

The Red and Grey Series.

By W. GIBSON

The detailed account will proceed from south to north, commencing with the eastern region.

The Basin of the Trent.

Black Band Group.—The shafts of the Florence Colliery pass through this group. The Bassey Mine Coal was met with at a depth of 895 feet 11 inches. If the base of the overlying Etruria Marls be taken at the horizon of the green rock (625 feet 2 inches in depth), the group is 270 feet 9 inches thick. In the Newstead boring the seam identified as the Bassey Mine was passed through at a depth of 1,946 feet. Taking the thickness of the Group at Florence the base of the Etruria Marls at Newstead should be 1,676 feet deep. Above this, in the boring, some 86 feet of grey measures were proved underneath the great thickness of red and purple beds of the Etruria Marls. It would therefore appear that the measures have expanded to the extent of 86 feet between Florence and Newstead.

Owing to the Florence Fault (p. 159) the Black Band Group does not crop out till nearly the centre of Longton. Several marl pits here illustrate the sequence. The southernmost is that of the Daisy Bank Marl Pit (Sect. No. 39, p. 449). These measures lie a few feet above the Bassey Mine Coal which is exposed in the Edensor Marl Pit (Sect. No. 38, p. 449), in which Mr. John Ward noted the occurrence of a limestone at a vertical distance of about 34 feet above the Bassey Mine Ironstone. At a distance of 280 yards to the south-west, or in the direction of full dip, the Longton Hall Marl Pit (Sect. No. 40, p. 450) gives a higher portion of the sequence. The limestone at the depth of 36 feet is a grey coloured fine-grained stone, in which Entomostraca are seen under the microscope to constitute the chief mass. The occurrence of this limestone is of some interest, as a black calcareous shale with *Spirorbis* and Entomostraca is found in association with a similar sequence in Hamptons Marl Pit (p. 451); and also as showing that in the southern as in the northern part of the area more than one limestone is present in the group. Between the Edensor Marl Pit and Longton Hall Marl Pit the strata formerly seen in an old marl pit would nearly complete the sequence, but it is now nearly filled up. The basal grits of the Etruria Marl Group crop out a few feet to the west of the shafts of the Longton Hall Colliery which thus pass through nearly

the total thickness of the Group. The shaft sections of the Glebe Colliery (Sect. No. 11, p. 395), Great Fenton Colliery and Oldfield Colliery (No. 10, p. 388), gives further details. All these collieries and marl pits are situated on the downthrow side of the Longton Fault (p 160).

The marls have been and are still used extensively for the manufacture of bricks, saggars, stilts, etc. On comparing the sequence at Longton and Fenton with the shaft sections of collieries further north it will be observed that many of the Black Band ironstones are missing in the southern part of the coalfield. The Bassey Mine at the Great Fenton Collieries is said to partake of the qualities of the Red Shagg, Red Mine and Bassey Mine ironstones, but this does not necessarily mean that the three ironstones have come together in the south. It is far more likely that the ironstones die out when traced in this direction.

From the Oldfield Colliery the outcrop of the Bassey Mine Coal extends northward until it runs into the Longton Fault near the junction of Duke Street with King Street, from whence the outcrop is displaced nearly 600 yards to the north-west. Its outcrop northward is obscured under Drift and buildings, but an old marl pit, now filled up, situated near Brunswick Street, worked the Peacock Marls—that is, the grey marls lying above the Peacock Coal—so that the outcrop cannot be many yards to the west. The Black Band measures become again exposed in Warrington's and Hewitt's Marl pits (Sect. Nos. 42, 43, p. 451). A fault of small throw crosses the south corner of Warrington's Pit, and is probably a branch of the fault proved in the Ash Coal to the south-west. A doubt exists as to whether the main fault passes between the two marl pits or whether it skirts their southern margin. From Warrington's Pit the outcrop of the Bassey Mine can be determined by several old shafts as far as Botteslow Farm, a little to the north of which it ends against the Ubberley Fault (p. 161). The break in the continuity of the outcrop at this spot must be considerable, for the Bassey Mine is next met with a little to the east of the Trent and Mersey Canal near Joiner's Square. Here a shaft, close to the western bank of the canal, reached the Bassey Mine at a depth of 31 yards. The outcrop is quite hidden and remains so till the Eastwood Marl Pit. This pit is being rapidly filled up, but a section across it is figured by Mr. Kidston,* in which a fault of 90 yards downthrow is represented as crossing the section. What is known as the 90-yard Fault possibly intersects the marl hole, but in the Shelton workings, to the north of the pit, the 90-yard or North and South Fault (p. 162) has only a throw of 22 yards.

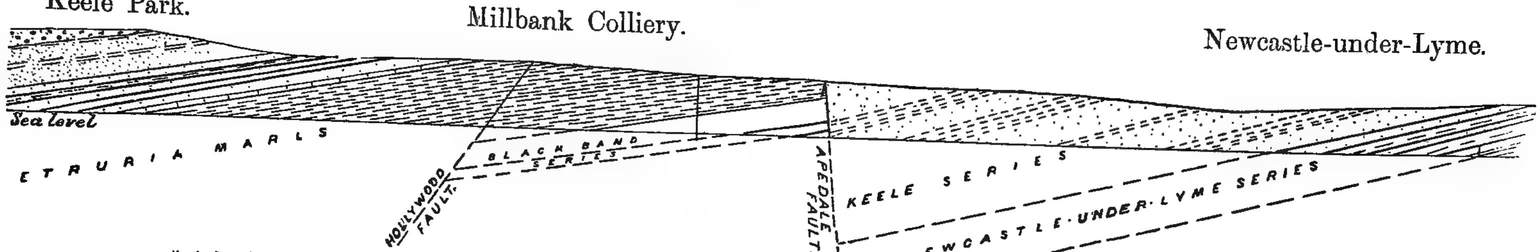
To the south of Hanley, two large marl pits, known as Hampton's (Sect. No. 44, p. 451), and Cannon Street (Sect. No. 45).

* *Trans. Roy. Soc.*, Edinburgh, vol. xxxvi., 1891.

Fig. 11.

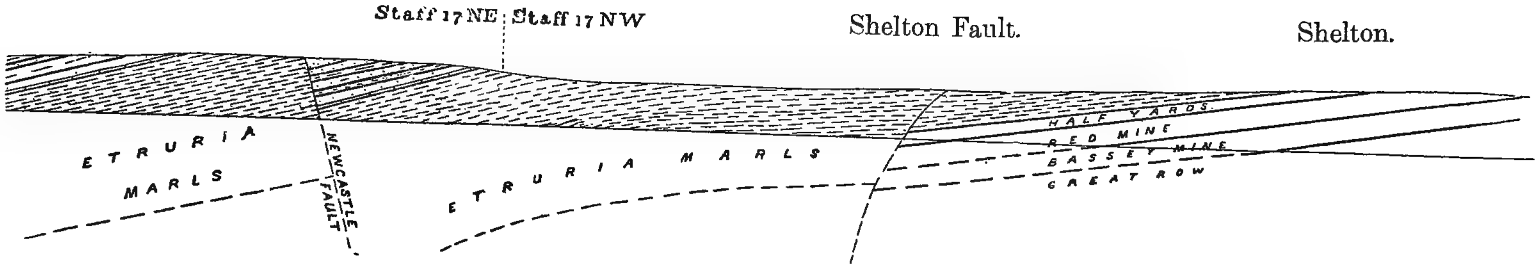
Section across the Red and Grey Series between Keele and Shelton. (Scale three inches to the mile.)

By W. Gibson.



* A boring reached the Red Mine at 501 yds. depth. *Trans. North Staff. Field Club.* Vol. xxxviii. p. 135.—1904.

E 12 N



p. 452), afford good sections. They are situated on the south side of the Shelton Fault. In both pits, as at the Longton Hall Marl Pit (p. 115), it is noticeable that the mottled red marls are immediately succeeded by a thin bed of shale crowded with Entomostraca. There is likewise a tendency for the various Black Band ironstones, which contain Entomostraca in abundance, to be underlain by mottled marls. This appears to indicate that the limestones, ironstones and shales with Entomostraca, represent the closing phase of a certain set of conditions one most likely of complete or nearly complete stagnation.

The Shelton Marl Pit (Sect. No. 46, Appendix III), situated close to and on the south side of the Shelton Fault (p. 163), affords further information about the measures.

To the north of the Shelton Fault the Group is penetrated by the Racecourse Pits (Sect. No. 16, Appendix III), and in part by the Rowhurst Pits (Sect. No. 17, Appendix III). In the Racecourse Pits the base of the Etruria Marls cannot be determined with certainty, but if it be taken at the red and grey metals above the thin coal, occurring at a depth of 54 yards, the Black Band Group would here be about 444 feet thick, a considerable expansion compared with the Florence section.

The Ladyswell Marl Pit, south of Brook Street, Hanley, exposes a good section of a portion of the measures, which will be seen to compare very closely with those in the Cannon Street Marl Pit.

Under Hanley the outcrop of the Bassey Mine is uncertain, but northward the numerous marl pits extending to Burslem Station fix its position with great accuracy. These are all large open pits about the horizons of the Peacock and Bassey Mine Coals, the marls being extensively used for bricks, saggars, stilts, drain-pipes, etc. The constancy in position, and the frequency and number of the limestones along this line of open excavations, will be gathered from the measured sections. The Group is further illustrated by the shaft sections of the Grange Colliery (Sect. No. 21, p. 424.)

To the north of Burslem the Black Band Group retains its general N.N.W. and S.S.E. strike, but at Newfield the dip assumes a more westerly direction, till at Golden Hill we reach the northern rim of the syncline. The exact outcrop of the Bassey Mine Coal is uncertain, but it can be fixed with some accuracy by means of old shafts and levels. The Red Mine and Red Shagg ironstones can be seen in the mineral Railway which branches from the Loop Line near the Pinnox Iron Works. A Black Band ironstone, high up in the Group, forms the floor of the Marl Pit at the north end of Tunstall to the west of the main road to Kidsgrove.

In the Diamond Pits (Clanway Colliery) the Red Mine Ironstone lies at a depth of 14 yards, the lower portion of the series being illustrated by the shaft sections of the Jubilee Queen Pits

of the same Colliery (Sect. No. 20, p. 423), and by several marl pits.

With the exception of the small east and west fault, south of Newfield, the rocks remain unbroken by faults up to that of the north and south dislocation skirting the western portion of Tunstall, and which at Brownhills Colliery has a westerly downthrow of 80 yards proved in the Red Mine. The Red Mine at a depth of 285 yards beneath the alluvium of the Fowlea Brook is nearly flat.

Between Golden Hill and Goldendale faults repeatedly break the continuity of the Bassey Mine outcrop. To the east of Golden Hill the limestone, which was exposed in a shallow marl pit near the roadside south of Colclough, affords a safe index to the position of this coal. To the west of Golden Hill the coal is at a depth of 25 yards in the Broadfield Colliery. From here to Ravenscliff the exact outcrop is uncertain. A level in a dingle to the south-east of Latebrook House reaches the coal a short distance from its mouth on the west or downthrow side of the Ravenscliff Fault (p. 164). The outcrop can be very closely fixed by the position of the limestone (yielding *Carbonicola Vinti* and a *Spirorbis*) exposed in an old marl pit 200 yards to the south of Ravenscliff House.

In No. 3 pit, Goldendale, the coal occurs at a depth of 117 yards. An ironstone said to be the Half Yards forms the summit of the quarry at the south end of the wood immediately north of No. 3 Pit, Goldendale. The marls below are crowded with plant remains aggregated into thin bands practically made up of vegetable matter.

On the west side of Goldendale the Bassey Mine was passed through at a depth of 6 yards by a shaft situated on the north side of the road leading from Goldendale towards Chesterton, at a spot 400 yards to the west of the bottom of the Valley.

Etruria Marl Group.—A narrow tongue of these marls extends southward from Longton to near Roughclose Common, between red rocks of Triassic age. The marls are penetrated by the shafts of the Florence Colliery which start about 50 feet below the limestone at the base of the Newcastle beds, which crops out in the mineral line. If the base be taken at the green rock (625 ft. depth), their total thickness is about 675 feet. It is not certain, however, if the outcrop of the limestone is natural, or whether it is faulted, as represented on the old edition of the survey map.

The most southerly point at which the marls are exposed is in an open excavation near Lightwood Lodge. The red marls here seen lying below the Newcastle beds are mottled red unlaminated clays. After maturing some time at the surface, they are carted to Stoke and used for tiles. On the opposite side of the valley near Cophurst Farm, red marls somewhat lower in the sequence are used for bricks. They are overlain by the Trias, which rests directly and unconformably on mottled red

marls containing lenticular bands of the greenish coloured grits so characteristic of the Group.

The marls are not seen north of the Florence Colliery, but they probably occupy the surface up to the Florence Fault.

In the Newstead boring, as previously stated (p. 115), the base is somewhat uncertain, but if it be taken at the indurated grey marl with bands of purple grit (1,593 feet depth), the thickness present is 756 feet, for the Newcastle Limestone was intersected at 837 feet.

On the upthrow side of the Florence Fault the marls come to the surface at Blurton Tileries. They lie near the summit of the Group. Small grains of a dark substance, which is probably sphærosiderite, or, at any rate, a carbonate of iron in some form, mark some of the bands. North of the Florence Fault and on the east side of the Trent Valley red marls form the surface between the river and the junction of the two main lines of the North Staffordshire Railway. The shafts of the Great Fenton Colliery pass through from 100 to 180 yards of red marl. A large quarry near the Bourne Shaft of this colliery exposes about 20 feet of a greenish coloured grit resting on purple marl. A grey sandstone and orange grit is also exposed in the railway cutting to the west of Mount Pleasant and in a marl pit a little to the north.

Greenish coloured grits towards the base of the marls are laid open in an old tram line to the south-west of Swingle Hill Colliery. Similar kind of grits, and occupying the same position, were excavated for the foundation of houses a few yards to the west of Fenton House, and serve in the absence of other data a means of determining the outcrop of the base of the marls on the downthrow side of the Longton Fault at Fenton. The marl pits seen on the south side of High Street, Fenton, where it crosses the Leek Line, are situated, judging from the abnormal dip northwards, close to the same fault. In the floor of the pit nearest to the road blocks of limestone with *Carbonia* could be picked up. From information on the spot it appears that the limestone was met with a few feet below the present floor of the quarry. It would, therefore, correspond in position with the limestone in the Grange Marl Pit (p. 121).

The hill on which Manor Farm is situated is composed of the lower portion of the Etruria Marls. The basal green grits form a small feature to the east and are cut through to the north of the farm house by the road leading from the Fenton Road to High Street.

On continuing the description northward and keeping to the east side of the Fowlea Valley, the red marls are seen to emerge from their cover of river and Drift deposits, on the western slopes of Shelton Hill, where the basal green grits crop out close to the church. It is probably this grit which is visible in Sun Street, Etruria Vale.

In the chapter on faults it is mentioned (p. 161) that in all probability the red marl at the Canal Tileries are over 1,000 feet thick, a further illustration of the tendency to a considerable expansion of the Coal-measures in a northerly direction, for at Newstead, four miles to the south, the Etruria Marls appear to be about 756 feet thick.

The following section gives the main details of the more southern of the two excavations of the Canal Tileries, Etruria.

CANAL TILERIES, CANAL SIDE, ETRURIA.

	FT.	IN.
Boulder-clay	5	0
Grey grit with a few plant remains	8	0
Red marl	6	0
Mottled red marl	9	0
Yellow marl	6	0
Mottled red marl	9	0

The beds are nearly horizontal, but in the pit to the north are inclined northward at a gentle angle.

On the upthrow side of the Shelton Fault the position of outcrop of the basal portion can only be determined approximately by the outcrop of the green grits at the surface near Sandbach Colliery, Grange Farm, and in Newcastle Street, Burslem. The shafts of the Racecourse Pits commence in the lower portion of the Group.

The marl pit near the Pump Pit of the Grange Colliery is interesting, as it shows the presence of a limestone developed near the base of the marls.

GRANGE MARL PIT, COBRIDGE.

	FT.	IN.
Yellowish-green sandstone	18	0
Grey limestone	1	0
Mottled red and purple marl	30	0

Under the microscope the limestone largely consists of the tests of *Carbonia* with an occasional *Spirorbis*. A thin calcareous band, but without organisms, occurs low down in the Group, in the Dale Hall Marl Pit, north of Newcastle Street, Longport, and in Peake's Tileries, Tunstall, all of which are large open excavations, situated on the downthrow side of the 80 yard fault (p. 163). Grit bands, from 20–30 feet thick, form lenticular bands in the mass of marls, but cannot be traced for any distance.

From here northwards we meet with few exposures. A sandy portion of the Etruria Marls is cut through by the road to the east of the Goldendale Ironworks, and dug for bricks in the Holly Lane Tileries, near Chatterley Station. The basal grit, underlain by a thin coal, caps the marl pit to the north of Sun Street, Tunstall.

Returning to the southern portion of the area, red marls are being extensively used for bricks, tiles, etc., at Hanford. The shapeless, isolated hill on which the village of Hanford stands is entirely surrounded by the alluvium of the Trent, and is bisected

by the Newcastle Fault (164), on both sides of which the marls crop out in the Hanford Brick and Tile Works. Red marls, in which lie thin lenticular bands of grit, form the bulk of the section. On the east side of the road a thin band of limestone caps the summit of the excavation. The limestone has been examined by Dr. Teall, who furnishes the following note:—

"The rock is composed of more or less rounded grains of limestone in a calcareous matrix. The grains (1·5 to 2 m.m.) are, as a rule, compact and do not show organic or oolitic structures. They resemble water-worn grains of a compact limestone. The matrix is composed of calcite with a few small grains (1 m.m.) of quartz."

It is doubtful if this represents a peculiar form of the limestone at the base of the Newcastle-under-Lyme Group, or whether it is the band developed lower down in the Basford Marl Pits (p. 123).

North of Hanford, at Trent Vale and Springfields, the marls are opened out in large brick pits, those to the east of the Black Lion Inn being traversed by a small fault. The usual greenish coloured grits are present in all the sections, and at Trent Vale a thin unfossiliferous band of calcareous grit lies in the floor of the quarry.

From Spring Fields the marls can be traced to the deep marl pit (Platts) near George Street, Newcastle, where they have been excavated to a depth of about 40 feet. They also just appear in the mouth of the tunnel near Newcastle Station, but north of this point are soon cut out by the Newcastle Fault.

The Newcastle Fault passing to the east of Trent Vale throws down the marls to form the lower slopes of the hill between Boothen and Stoke-upon-Trent. At Stokeville a recently opened brick pit shows the junction of the marls with the Newcastle beds to be a fault with a steep hade to the north-west and trending N.N.E. and S.S.W. The marls are brought against a thin coal, curiously folded and disrupted. On the north side of the Penkhull Road, near Ashfield Cottage, the natural junction of the Newcastle-under-Lyme Group and the red marls becomes visible in the following large open excavation:—

MARL PIT, PENKHULL ROAD, STOKE-UPON-TRENT.

	FT.	IN.
Yellow shales and grey sandstones	12	0
COAL	1	10
Shales	11	0
Limestone	0	10
Shales	0	6
Limestone (Base of Newcastle-under-Lyme Group)	0	3
Red Marls	20	0

The lower slopes of Penkhull Hill facing Stoke-upon-Trent and Shelton are unopened till close to Harts Hill Farm, where the Etruria Marls underlying the grey Newcastle beds are excavated in the brick and tile works near the Railway. From here northward to Longport a series of Brick and Tile works

afford excellent sections, clearly illustrating the gradual passage of the Etruria Marls into the Newcastle-under-Lyme Group.

Bands of grit are present in all the pits, but those towards the summit of the Basford Tileries are the coarsest, and occasionally resemble the conglomerates of the Millstone Grit. In most of the excavations a thin irregular band of a highly-calcareous rock occurs between 60–100 feet below the summit. It is apparently unfossiliferous, but evidently occupies the position of the *Spirorbis* limestone in the Chesterton area (p. 130).

Red marls form the slopes of Bradwell Wood, but their full thickness is not seen, as they are traversed by the Bradwell Wood Fault (p. 163). In the Brown Hill Colliery, the Red Mine, on the upthrow side of the Bradwell Wood Fault, is 285 yards below the surface of the alluvium, a little north of where it is crossed by the mineral railway. The strata are nearly flat. The limestone at the base of the Newcastle Group crops out on the 500 feet contour-line in Bradwell Wood—or 100 feet above the surface of the alluvium. In the Grange Colliery the distance between the Red Mine and base of the Etruria Marls is 96 yards. There are, therefore, 567 feet of Etruria Marls below the alluvium. Adding 100 feet for the rise in the ground and 300 feet for the amount of downthrow of the Bradwell Wood Fault, it is seen that under Bradwell Wood the Etruria Marls are 967 feet thick at least. As the strata dip gently towards Bradwell Wood on the west side of the Bradwell Wood Fault the true thickness would be slightly in excess of this estimate.

The red marls cropping out to the north and west of Bradwell Wood may be considered to belong to the western area, under which heading they are described.

Newcastle-under-Lyme Group.—The most southerly point where these rocks are exposed is the Marl Pit near Lightwood Farm, of which the following section gives measured details :—

MARL PIT, LIGHTWOOD FARM, COCKNAGE.

	FT.	IN.
Grey flags - - -	12	0
Limestone—*Carbonia, Spirorbis*	0	6
Grey shales—*Carbonia, Estheria*	3	0
Limestone	0	4
Grey shales - - - - - -	0	10
Mottled red marls (Etruria Marl Group) -		

The Group apparently occupies a narrow strip of land between the elevated tract formed of Triassic rocks as far as Roughclose Common. In a gutter near Woodend Farm a thin coal is said to have been laid bare in a ditch. North of Lightwood Farm the Group becomes buried under the Trias, and is almost certainly bounded by a fault. Grey measures and a thin coal were passed through in a well in a garden situated on the west side of the road near Coldriding Farm. Thence,

northward, the outcrop of the basal portion is uncertain, but the limestone was intersected by the mineral line from Florence Colliery to Trentham. It is overlain about 50 feet above by a thin coal succeeded by grey sandstones and shales.

The Group probably underlies the Drift of Longton Park and strikes for the Stone-Road Fault south of Longton Lea. In a gutter near Blurton Cottage fragments of a coal are visible, possibly the same seam intersected by the Florence cutting.

At Blurton Tileries a narrow patch of grey measures is surrounded by faults, close to one of which the limestone crops out on the eastern side of the marl pit. Several trial-holes and borings elucidate the complicated structure at this locality, details of which will be found in the appendix (Sects. Nos. 55-57). It is evident from this information, and from that obtained from a shallow shaft sunk to the north of the mineral line, that the strata are arranged in a local syncline bounded by faults.

In the Newstead boring, which gives the key to this area the base of the Group can be safely drawn at the limestone at 837 feet depth; and the summit, but with a less degree of accuracy, at 551 feet, the thickness therefore being 286 feet.

These grey measures do not occur on the east side of the Trent north of Blurton except at Hanford, where, south of the Tileries, judging from the light-coloured soil, they compose the highest ground. On the dip slope to the south they are covered up in a short distance by the Keele Sandstone, thus giving a very limited width of outcrop, and favouring the supposition that the junction with the red marls below is a fault. On the downthrow side of the Newcastle Fault at Hanford the basal limestone, with Entomostraca and fish remains, crops out on the by-road to Sideway Farm, while to the south there are several shallow exposures in grey shales and sandstones.

West of the Trent, from Stoke Lodge to the north end of Bradwell Wood, the grey group forms a conspicuous escarpment, constituting the dominant feature in the landscape to the west when viewed from the railway between Stoke-on-Trent and Chatterley Station. Sections Nos. 59-60, Appendix, show the character of the basal portion and its relation to the underlying Etruria Marls. In some of the marl pits the junction is irregular. This does not signify an unconformity, as such a junction might be expected where fine-grained sediments representing tranquil deposition are succeeded by coarser materials when sedimentation became more rapid. Throughout the Coal-measure sequence it is the rule for the grits and sandstones to lie irregularly on the softer strata.

Between Stokeville and Hartshill the width of outcrop seems much too narrow to allow for the full thickness of the Group to be represented, and it is probable that a portion is cut out by a fault.

Between Hartshill and Basford a marked break in the escarpment suggests a fault, but its existence cannot be proved. In the marl pit north of Hartshill Farm the Newcastle beds appear to have slipped slightly down the hill over the Etruria Marls, and not to be faulted, as is sometimes locally suggested.

Two coals and a portion of the strata above and below are exposed in the eastern section of the railway cutting, Newcastle-under-Lyme. The basal limestone stands out conspicuously in the road cutting at Basford, and a seam of coal, 1 foot 6 inches thick, traversed by a small fault, projects in the roadside at Bank House. A short distance to the north Mr. Stobbs observed in some foundations excavated close to the junction with the overlying Keele sandstones, nodules of a blue-hearted calcareous sandstone.

From Basford to Longport the stratigraphy is clear, owing to a continuous line of large open excavations In the Midland Tileries small east and west faults cross the general strike. At Wolstanton the width of outcrop is broader than usual, owing to the local decrease in the amount of dip and to the slope of the ground westward approximating the inclination of the strata.

At Longbridge Hays a conspicuous break in the feature marks the position of a small fault depressing the strata to the north. The quarry at the south end of Bradwell Wood has supplied a considerable number of interesting plant remains (see Part III., p. 336).

Further north the Group caps the summit of Bradwell Wood, and the basal portion can be followed by the sudden rise in the ground and by the occurrence at intervals of the limestone or the accompanying shales containing Entomostraca, and a small shell, probably *Anthracomya calcifera.*

Keele Group.—The red sandstones and marls of this Group cover a considerable area of low-lying ground to the south of Dresden, between the Trent and the triassic hills on the south and east.

The Newstead boring is situated towards the centre of this area, and proved the Group to be at least 550 feet thick, consisting of alternations of red sandstones and marls, with an occasional thin band of black shale and bass (403 feet depth). Strata of a grey colour occupy a very subordinate position. A dark calcareous band at 378 feet depth closely resembles a thin bed in the railway cutting at Keele Park with which sequence the boring bears a close resemblance. At the base, a band of red laminated ironstone contains abundant remains of Entomostraca, and a few fish remains. Below this come a few feet of fireclay overlying a bright coal five inches thick. It is a matter of opinion whether to include these beds in the Keele Group or to place them at the top of the underlying Group.

On the flat ground south of Newstead exposures are scarce, but the persistent crimson colour of the soil indicates that the Keele Group underlies the surface. Solid rock, in each case consisting of red sandstone, crops out at Trentham Ley, Barlaston Village, and Parkfields. In a quarry to the north-east of Newstead Wood, red sandstones with lenticles of a calcareous breccia dip westward. The same inclination is observed at Barlaston Village, about one mile due south. About one-and-a-half miles further south in an old quarry north of Meaford Farm, false bedded red sandstone of the Keele type is inclined to the S.W. It is possible that all these exposures giving a westerly dip are situated close to a north and south fault, as is in part represented on the old edition of the map.

Eastward of this line there are no exposures to indicate the amount or direction of dip, so that it is impossible to calculate the thickness here or to determine the correct structure of the area.

In the small brook running from the old moat at Hartwell to Lower Moddershall occasional glimpses of solid rock can be obtained. The inclination remains at a gentle angle southwards. At Lower Moddershall Mills a good exposure of red marls and flaggy red sandstones by the roadside and in the stream shows a slight southerly inclination, apparently continued as far as Mostyley Mill, near which the strata become buried beneath the Bunter. In the by-road from Lower Moddershall Mill to the Stone Road a dark blue nodular limestone lying in crimson marls crops out on both sides of the road. The limestone contains Entomostraca and traces of other but indeterminable organic remains. The position of this limestone is uncertain, but it closely resembles one of those found high up in the Group in the western area. A coal over one foot thick, lying in grey shales crops out in a small wood near Moddershall Mill. The evidence points to these grey beds belonging to the Keele Group, for red sandstones surround them on all sides; but the actual junction is not visible. The coal is no doubt the one obtained in an old shaft further south, as shown on the map.

A narrow tongue of the Keele Group almost certainly lies at the surface in the deep hollow between Rough Close Common and Knenhall. There are no exposures, but the banks of the many ponds show crimson marl, while fragments of the characteristic lavender sandstones lie scattered over the surface. At one spot only, in a shallow excavation to the east of Berry Hill Farm, are there any indications of Drift, so that it is reasonable to conclude that the sandstone fragments represent solid rock near at hand, and have not been carried here by glacial action.

From the north end of Cocknage Hill to Blurton a marked rise in the ground indicates the outcrop of the basal beds. The characteristic red sandstone forms the high banks of the road at Blurton Village, and the feature it gives rise to can be traced northward till it dies out at the Florence Fault.

The large downthrow of the Newcastle Fault causes the Keele sandstone to cover a considerable area on Penkhull Hill. The sandstone has been quarried at several places. At Quarry Bank it contained some interesting plant remains collected by Dr. Garner and preserved in the Museum, Stoke-upon-Trent. These have been examined by Mr. Kidston * who finds them to be all of carboniferous species.

Between George Street and May Bank, a narrow strip of red sandstone clings to the Newcastle Fault. Quarries have been opened near George Street, a few yards to the north of Stonyfields and near May Bank Cottage. It was also passed through in the Newcastle Tunnel. At Port Hill, the sandstone crops out near the junction of the Longport and Wolstanton roads, and forms a fairly definite feature for some distance northwards, but the outcrop is probably affected by branch faults from the Newcastle dislocation.

The Western Region.

Black Band Group.—The Apedale Fault (p.165) has determined the workings of the Black Band Ironstones. These are obtained on the east or downthrow side of the fault in the Chesterton area, where the rise to the north brings the ironstones within easy reach; and on the upthrow side to the north of Silverdale.

In the Chesterton region the outcrop of the Bassey Mine has not been definitely determined, but the Red Mine Ironstone is stated to crop out 200 yards to the S.S.E. of Springwood. In the Hem Heath Colliery the Red Shagg Ironstone is intersected by the shafts at a depth of 275 yards, and in the Parkhouse Colliery at a depth of 340 yards; the Half Yards being met with at 320 yards depth, and the Red Mine at 360 yards. In the High Carr Colliery, situated in the trough between the High Carr Fault (p. 164) and Bradwell Wood Fault (p. 163), the Red Shagg Ironstone was met with 260 yards below the surface.

To the north of High Carr, the High Carr Fault, taken in conjunction with some faults having a north-westerly trend and a down-throw to the south-west, encloses a small area of the Black Band Group. These beds are intersected by the Jamage mineral line, in which the Bassey Mine Ironstone and Coal are cut through 200 yards east of the point where the line is crossed by the lane from Red Street to Peacock Hay. The limestone with *Spirorbis* occurs at about the usual distance above, and below the ironstone comes a group of thin coals. About 50 yards west of the spot where the road to Newcastle

* Summary of Progress of the Geological Survey for 1899, p. 109.

crosses the mineral line, the Bassey Mine Ironstone and Coal, with the limestone above and thin coals below, are again seen. There is no doubt that this repetition of the sequence must be accounted for by faulting. The Bassey Mine Coal, however, is stated by Mr. Sumnell to crop out where the lane from Red Street crosses the road to Newcastle, the Red Mine Ironstone and Half Yards Ironstone reaching the surface successively to the south-east, while an old shaft 80 yards north-west of the Bassey Mine outcrop is stated to be on the Great Row Coal at little depth. A second fault has therefore been introduced to account for the outcrop of the Bassey Mine in the western portion of the Railway.

The following section of the Red Shagg Ironstone and underlying measures was obtained from Mr. Sumnell:—

RED SHAGG IRONSTONE, HIGH CARR COLLIERY.

		Thickness. Ft.	Thickness. In.
Ironstone with cone-in-cone structure	Red Shagg Ironstone	3	6
Red Grit - -		1	3
CANNEL - - - - - - -		0	2
Ironstone with *Lepidodendron* - -		2	8
RED SHAGG COAL - - - - - -		1	6
Isaac (Shale bass) - -		0	4
Oil Shale - -		1	3
Stone -		3	0
COAL		1	3

In the district to the west of the Apedale Fault, the name Bassey Mine has been applied to a black band ironstone occurring above the Red Shagg Ironstone, the Bassey Mine of the eastern area being known as the *Pottery Bassey Mine.*

At Silverdale and Apedale the outcrop of the Pottery Bassey Mine is uncertain, but it is possibly the thin laminated ironstone at the top of the disused marl pit (see section p. 102) near the Apedale Ironworks. The Lily Pits start a few feet below the outcrop, which would seem to strike thence for Grubbers Hill Farm, and from there for the old railway cutting to the north of Silverdale Ironworks but it cannot be detected here with certainty. The Red Mine crops out at an old level in a small gully to the east of Grubbers Hill, and is being brought to the surface by a level to the north of Black Bank. The Whitebarn, Gorsty Bank and Old Grove collieries formerly raised the chief ironstones. On an old plan of the Knutton Farm Colliery the following depths and thicknesses are shown* :—

KNUTTON FARM COLLIERY.

	Depth. Yds.	Thickness. Yds.	Thickness. Ft.	Thickness. In.
Black Band Ironstone -	110	1	0	4
Red Shagg Ironstone	122	1	1	0
Red Mine Ironstone -	144	2	0	0

* In the Mining Record Office.

The ironstones are underlain by coals, that below the Black Band being over three feet thick. In the Millbank Colliery 900 yards to the south the depth to the Red Mine is 172 yards.

The inclination of the strata decreases from 25 degrees at the Marl Pit, Apedale, to 10 degrees a little north of Church Street, Silverdale.

Information at the south end and along the western margin of the anticline is scanty. At the south corner of the Madeley Heath Brick Pits a faulted anticline of grey shales and a thin coal becomes clearly discernible. Whether these belong to the Black Band Group or represent the grey strata occasionally present in the Etruria Marls (p. 130) is not certain. In the white clays overlying the coal a nodular band of a calcareous rock contains a few Entomostraca, and may thus represent one of the limestones of the eastern region. The Madeley Heath Brick Pits are certainly in the Etruria Marls; while in the Dingle Pits a short distance to the north the Cannel Row was reached at 83 yards depth. We have been unable to determine the thickness of the sub-divisions of the upper measures in this area, but there would seem to be too small a space between the brick yard and the Dingle Pits for the full amount of the Black Band sub-division. The outcrop is probably complicated by faulting, and not so simple as represented on the map.

On the western margin of the anticline the Black Band Group must be at the surface in Walton's Wood, for the Black Band Ironstone crops out on the eastern margin of the wood. Grey measures and a thin coal were also obtained in a shaft near the bottom of the ravine to the east of The Glading. In an old shaft, a few yards north of the side stream, leading into the main stream flowing through Walton's Wood, the Pottery Bassey Mine is shown on an old plan to be 20 yards deep.

In the much-faulted and complicated area north of the Hollywood Fault the presence of the Black Band Group at the surface needs further confirmation. The scanty information to be obtained at the surface points to their being cut out by faults. Near Great Oak, three-quarters of a mile north-east of Audley Church, a trial shaft was sunk some years ago by the late Mr. William Rigby, but was abandoned, in the belief that the workable coals lay at too great a depth to be remunerative. The material seen around the shaft consists of light grey sandy shale, and possibly belongs to the Black Band Group, the Etruria Marls having cropped out a short distance further west.

Etruria Marl Group.—On the western side of the Lyme Valley from the fault near Northward Farm to that opposite Spring Fields the presence of these beds can be inferred from the red colour of the soil, and from occasional shallow excavations in red marl.

A narrow strip of red marls between the branches of the Apedale Fault extends from Hanchurch to a little north of Butterton New Farm. In the road cutting (Sect. No. 61,

Appendix), and in the fields to the north, the marls are visible. They also appear to be present on the upthrow side of the Apedale Fault, judging from the red marls exposed in an old excavation in a field situated on the west side of the by-road leading from Hanchurch to Butterton.

A long tongue of red marls extends from The Cloughs to Shutlanehead, where they were formerly worked in a large marl pit. They are also to be seen behind the rifle butts, and in a shallow pit a few yards to the north; but eastwards, owing to the absence of exposures, the evidence for extending the outcrop up to the Apedale Fault is of the slenderest character.

Red marls, to a depth of 50 feet, are excavated immediately to the south of Rosemary Hill Colliery, and also on the north side of the railway near Knutton Farm Colliery.

The base of the Group north of Silverdale may be represented by the yellow-green grits in red marl cut through by the Market Drayton line and by the old tram line north of Newcastle Street, for they closely resemble the grits towards the base in the eastern area. Red marls overlain by grey grits are also to be seen in an old clay pit near the Grove Colliery.

From the Grove Colliery the Apedale Fault throws the marls nearly a mile to the north. They are extensively quarried around Chesterton, and exhibit an interesting sequence. The base consists of an olive-coloured grit, which has been cut through by the road north of the Chesterton Pits, and again by the mineral line to the west of Birkhouse Colliery. In the marl pits to the south of the Chesterton Pits the top of the excavation is composed of yellow flags resting on a band of laminated ironstone over a foot thick, and crowded with *Anthracomya Phillipsi.* The ironstone rests on a thin coal; and a few feet below, red marls, resting on a pale olive-coloured grit, are excavated. The slope of the escarpment as far as Chesterton Hall is also composed of red marls. On the upthrow side of the fault at Chesterton the pale grit caps the marl pits near Birchhouse Colliery, while the grey flags, ironstone, and thin coal are exposed in the Rose Vale Brick Pits to the south-east of Hem Heath Colliery. The eastern portion of this quarry is crossed by a small curving fault with a downthrow of a few yards to the north-east. In the Hem Heath Colliery the Red Shagg Ironstone lies at a depth of 275 yards, so that the coal and ironstone seen in the marl pits lie high up in the Etruria Marls. On the south side of the mineral line in the Metallic Brick Pits the portion of the marls immediately below the Newcastle limestone are extensively quarried. At a distance of about 80 feet from the summit a line of calcareous nodules, containing *Spirorbis* beautifully preserved in calcite, extends across the quarry.

In the Parkhouse Colliery further to the north-west the Half Yards Ironstone is 320 yards beneath the surface, giving from 850 to 900 feet of the marl in the shaft. The inclination in the

ironstones is 11 degrees, and the Newcastle limestone crops out 350 yards to the south-east in the direction of dip. Allowing for a rise in ground of 50 feet, the thickness of the marl sub-division at this locality is, therefore, between 1,000 and 1,050 feet.

A yellow rather massive sandstone and yellow flags are cut through by the mineral line 400 yards to the north-east of Park-house Colliery. The ground is here very faulty, and some land-slipping has taken place, so that the position of these grey measures is uncertain, but they apparently lie in the Etruria Marls, which can be seen cropping out in the stream banks to the north and behind the rifle butts on Bradwell Hill. In the High Carr Tileries, situated to the north of the colliery, an interesting section of a portion of the marl sub-division is laid open:—

HIGH CARR TILERIES.	Thickness. Ft.	In.
Red marl	30	0
Olive-coloured rock	14	0
Purple marl	6	0
Red marl	30	0

A specimen of the olive-coloured rock was examined under the microscope by Mr. Barrow, from whose notes the following description is taken: "A fair amount of calcite and some of a soft, green serpentinous material is present. Fragments of quartz are abundant, many of them containing numerous cavities and some needles of rutile. From their form they have come directly from acid igneous rocks, and in several instances the fine rhyolitic matrix is seen adhering to the quartz crystals. Here and there patches of very fine pegmatitic material may be made out, in which the original felspar has been replaced by the green decomposition product permeating the rock. A few fragments of a moderately basic igneous rock are also present."

North of the Birchhouse Colliery the basement grit forms a bold ridge on which Birchhouse Farm is situated. It is traversed on the south and probably also on the north by faults. At Crackley the feature becomes less distinct, and north of here, as far as High Carr, disappears altogether. At High Carr the grit again makes a strong feature and is well exposed in the road-cutting, from whence it can be traced as far as Bell Brook, south of the Jamage mineral line.

A good section in red and purple mottled clays, containing a higher band of a coarse-grained, green grit several feet thick, is seen in the Downing Clay Pit south-east of Crackley. The grit makes a decided feature, which can be traced as far as the road to Newcastle, where it is cut off by the High Carr Fault. West of here a fine section in the Bradwell Hall Marl Pit, but at a slightly lower horizon, shows no grit. The dip is south-east at about 25 degrees. Newhouse Farm stands on another

and still higher bed of coarse-grained greenish yellow grit, which at first sight looks to be continuous with that in the Downing Clay Pit; but the apparent continuity is fallacious, for they are in reality separated by the High Carr Fault.

Returning to the southern portion of the anticline, the Hollywood Fault (p. 174) forms the boundary of the sub-division between Silverdale Farm and the Hollywood Pit. The Silverdale Tunnel passes through red marl, exposed at its northern end, and also to be seen in the Silverdale Tileries and in the wood to the north of Keele Station. West of the Hollywood Pit the outcrop is uncertain, but fragments of the green rock lying about the surface probably indicate the position of the base north of Finney Green.

The Madeley Heath Brick Pits exhibit a section of the marls in which several bands of an olive-coloured grit are developed. Sections can also be obtained in Hazel Brook between the Viaduct and Ridgehill. In the Ridgehill Brick Pits, which show over 50 feet of red marl, a thin band of grit resembling the Keele Sandstone is present towards the summit of the excavation

The solid geology round Little Madeley and to the south is obscured under a thick deposit of Drift, chiefly sand and gravel.

North of the Hollywood Fault on the western margin of the anticline the red marls at the surface between Hayes Wood and the Minnie Pit must certainly be taken to belong to the Etruria Marls. What portion of the Group is here represented is open to doubt, for it is uncertain if the grey sandstones and shales which overlie the mottled red marls seen on the western slopes of Hayes Wood, and in a disused quarry a few yards north of Hayes Farm, belong to the overlying subdivision or are on the horizon of the grey measures seen in the Rose Vale Brick Pits (p 130). In an old level at the south end of Hayes Wood, on the western side of the valley, a laminated ironstone and also a black shale crowded with Entomostraca were obtained. A similar kind of shale can be picked up on the fields near Ridgehill Farm, where the base of the overlying subdivision is probably close at hand (p. 134). Further north a crut driven from the bottom of the valley towards the east passed first of all through red marls and then troubled ground. The Minnie Shaft sunk on the line of western disturbance offers little reliable data, while Drift clays and sands deeply cover the rocks to the north. From the presence of the black shale with Entomostraca we are however inclined to consider the grey sandstones of Hayes Wood to belong to the Newcastle Group.

Further north purple marls blotched with green appear from under twelve feet of Boulder-clay in a marl pit a quarter of a mile east of Audley Church. Specimens of red marl, purple micaceous marly sadstone and marl brecca, obtained in a well sunk at the east end of Chapel Street, half-way between Audley Church and the Station, show that the Etruria Marls underlie this area.

Newcastle-under-Lyme Group.—On the west side of the Lyme valley the outcrop is well defined from the fault at Northwood Farm to a short distance north of Clayton Hall. The sudden rise in the ground to the east of Northwood and Clayton Hall denotes the position of the base, while the belt of light-coloured soil, in sharp contrast to the red soil of the Keele sandstone to the south and west, indicates the breadth of outcrop. Around Hanchurch, to the west of Northwood, the subdivision comes to the surface between the branches of the Apedale Fault, an insight into the nature of the measures being afforded by the road section near Butterton New Farm (Sect. No. 61 Appendix). The basal limestone, in which fish remains are fairly abundant, consists of an irregular bed difficult to find, but the associated shales are well shown on the south side of the road near the corner of the plantation. The coals higher up, no doubt, correspond to the two lower seams in the railway cutting at Newcastle.

There are several limited exposures at Hanchurch and round the fish ponds near which a thin coal crops out. To the west of the small branch fault crossing Butterton New Farm grey sandstones and flags have been quarried in a field to the west of the by-road from Hanchurch. In the dingle near the south lodge gates of Butterton Park, grey sandstones, flags and shales occupy the bed of the stream for some distance to the north east, where they are brought up by a fault against red sandstones of the Keele type. The dislocation is not seen, but as red sandstones are unknown among the Newcastle Group a fault seems the simplest solution of the phenomenon. The excessive jointing of the grey sandstones in the quarry near the lodge gates also indicates the proximity of a fault, and moreover the area is situated on the line of the great Apedale disturbance.

The presence of the basal limestone in the north banks of the pool at Shutlanehead and the occurrence of a thin coal in grey shales in the clay pit to the south, taken in conjunction with the undoubted existence of the Etruria Marls in the clay pit to the north, proves the existence of the subdivision at this spot.

The evidence for the continuation northwards is scanty, and consists mainly in the presence of a distinct feature which can be followed from Oxhay Wood into Springpool Wood where grey shales are exposed along the stream course, and can be traced thence to Brick-kiln Plantation where the basal limestone becomes again visible. In Rosemary Hill Wood the Etruria Marls are overlain by grey shales, at the base of which a thin calcareous grit with *Spirorbis* is developed. Thence to the north-west a prominent feature indicates the outcrop as far as to the fault south of Knutton Manor Colliery. At the northern end of the dingle at this spot the grey sandstone has been quarried, and a coal over three feet thick is said to have been found below the floor of the quarry. From Knutton Manor Colliery to Silverdale farm the junction with the Etruria Marls is evidently a fault. The narrowness of outcrop on the north flanks of Redheath

Plantation suggests a fault, which is further confirmed by the indefiniteness of the outcrop to the south-west. Between the Keele Road and Honeywall three bore holes (sect. Nos. 63–65 Appendix) have been put down. No. 5 is situated 50 yards north of Honeywall Farm, No. 7 is near the mouth of the tunnel, and No. 6 close to the coppice on the south side of the Keele Road. It is difficult to identify the records with the local sequence, especially the numerous ironstones mentioned.

The subdivision is probably at the surface between the faults at Dunge Wood and Ridgehill. Grey sandstones and shales with thin coals were passed through in the tunnel, and grey sandstone has been quarried 200 yards to the west. A few yards to the north of the quarry some old excavations, now grassed over, seem to have exposed a black shale crowded with Entomostraca, and at the spring 53 yards south-east of Ridgehill Farm grey flags and shales rest on mottled red marls. The presence of the Newcastle Group would therefore seem to be established in this locality.

In the Chesterton area the basal limestone lies near the foot of the strongly-marked escarpment overlooking the town to the north. During the excavations for telegraph posts at Beazley Bank the limestone was exposed. *Anthracomya calcifera** occurs in fair abundance, beautifully preserved in iron pyrites besides *Carbonia*, Fish remains and *Spirorbis*. The limestone is also to be seen on the banks above. At Chesterton Hall the line of scarp becomes broken, and the basal bed thrown 150 yards to the north-west by the Chesterton Fault; after which the feature resumes its prominent character to the west, until it joins the large Apedale Fault to the north-east of the Apedale Ironworks. Blocks of the limestone lie at the foot of an old excavation 300 yards west of Mount Pleasant.

On the extreme western margin of the coalfield the group is probably present on the west side of The Glading, and probably also in Hayes Wood (p. 132). It is undoubtedly at the surface in the Audley district. The strata, as seen in the road-cutting immediately north of the Church, consist of rather hard white micaceous sandstones, in places slightly purplish, with white shaly and marly beds in the lower part containing ferns and other plants. It is said that when the road-cutting was made two seams of coal were found, but only fragments in the soil can now be seen; a seam three feet six inches thick is also said to have been met with near the surface, about a quarter of a mile slightly west of south from the church. The junction with the Etruria Marls is not visible, and no fragments of the basal limestone are found lying about. The ridge formed by the sandstones makes a prominent feature, on which the village of Audley mainly stands. The feature diminishes about half a mile south of Audley, and dies out northward just before reaching the Red Rock Fault (p. 187).

* Wheelton Hind : *Quart. Journ. Geol. Soc.*, vol. lv. (1899), p. 367.

Keele Group.—Red sandstones and marls cover an extensive area on the downthrow side of the Apedale Fault between Trentham and Chesterton. The warm, deep, red colour of the soil, affording a pleasant contrast to the dull tints of the measures below, at once strikes the observer passing through the Pottery Coalfield to Market Drayton.

The sandstone, always much jointed, has been excavated in places for walling and building stone, notably at the Kennels, Trentham Park; the Cemetery, Newcastle; and a little south of Chesterton Hall.

At the spring, in Spring Vale, Trentham Park, the stone locally assumes a brown tint, and is traversed by numerous cracks and joints. A little north of Knutton Ironworks some trial holes in search of brick clays proved that the sandstones are interstratified with red and purple marls, bearing a very close resemblance to the marls used for terracotta near Wrexham in the Denbighshire Coalfield.

It is locally stated, but the report needs confirmation, that at Dimsdale Hall a coal was struck in a cellar. Around the Hall and in the by-lane red sandstone and flags of the Keele type are seen, but the resident does not seem to have observed any indication of coal on his land.

In an old shaft, known as Clews Shaft, to the east of the Apedale Ironworks on the downthrow side of the Apedale Fault, red sandstone was passed through. The water in this shaft was drained off by a shallow shaft in red sandstone sunk at the Knutton Ironworks, which are also situated on the downthrow side of the Apedale Fault.

West of the Apedale Fault the group occupies an irregular area, much broken by faults and unconformably overlain on the south by the conglomerates and sandstones of the Bunter. The sequence is admirably illustrated, in part, by the railway cutting at Keele Park Racing Station (Sect. No. 62 Appendix). The chief interest of the section lies in the band of limestone with Entomostraca. The marls seen in this section are seldom visible at the surface, since they generally occupy the dip slopes and lower ground almost universally grass covered. The thickness of the group cannot be given, as the strata are buried by the Trias to the south, and there are indications between Netherset Hay and Oxhay Wood of the strata being crossed by a strike fault repeating the sequence to the north. The inclination from the railway cutting to the margin of the Trias between Whitmore and Snapehall is always southerly, and is frequently as high as 20 degrees. This would imply a great thickness, but the possibility of folds and faults must be borne in mind. From a comparison with other areas in the Midlands the highest beds would appear to be represented by the brown flags and thin calcareous bands exposed in the dingle near Moat House Farm. The narrow and straight peat-filled valley between Whitmore Station and Madeley Station suggests a fault. The Trias

on the west side of the valley would also appear to be banked up against a fault repeating the beds to the west. The sandstones and calcareous breccias cut through by the railway to the west of Madeley Road Station and visible in the roadside north of the station certainly bear a very close lithological resemblance to those of the Keele Park railway cutting.

The same red Keele rocks are exposed along the southern part of the anticline uplift from Madeley to Mucklestone and Loggerheads. As neither the summit nor the base can be seen, and the inclination is very variable, it is impossible to estimate the thickness. As far as seen the rocks consist of purple, brown and grey, and sometimes whitish sandstones, usually highly felspathic and weathering to a crimson marl. Occasionally a more quartzose bed occurs, which weathers to a brown sand, and sometimes contains small quartz pebbles. It is probable that soft marls are intercalated with the sandstones, though they are not found in any of the sections. Two thin nodular limestone bands have been found. One of these cropping out in the ponds immediately north of Rough Canker Wood, south-west of Willoughbridge, consists of a layer of nodules of dark blue limestone full of entomostraca. The nodules are of irregular shape, suggestive of the solution of a continuous band of limestone. The other limestone was not seen in place, but its presence was indicated by a considerable quantity of the *debris* of a hard white crystalline unfossiliferous limestone seen in the bottom of a marl pit near Sidway Hall, Pipegate.

On the Keele Park Estate the sandstones have been extensively quarried round the Hall, near Bog's Cottages and Redheath Plantation, the stone being excavated for the Hall, Keele Church, and for the wall round the estate.

In making the Racecourse at Keele Park a coal over a foot thick was laid bare near the northern margin of the track. In the road section to the north, and in drains and ditches to the south, red sandstone and marls clearly crop out inclined towards the exposure of the coal. It would, therefore, appear that the coal seam lies in the Keele Group. A shaft sunk on the south side of the track to a depth of 28 feet passed through grey shales but failed to reach the coal. In a depression near Swallowcroft Wood there appears to have been a level on this seam, but it is now concealed under *débris*.

The position of a light brown limestone with *Spirorbis*, sparingly met with, in Dunge Wood, is uncertain. It lies in a series of purple marls and sandstones of the Keele type, and would, therefore, appear to belong to this group; but the area is so faulted that this may not be correct.

Red sandstones of unmistakable Keele type appear at the surface on the west side of the Bar Hill disturbance at Madeley Manor House on the northern slope of the hill. They are also visible in a much disturbed state close to the fault at the north end of the fish pond.

On the north side of Checkley Brook the exposure in a small dingle to the east of Heighley Castle Farm, and the colour of the soil to the north, is sufficient to show that the group occupies the high ground between The Glading and the outcrop of the Bunter to the west; but this solitary section affords the only evidence.

In the Audley district no rocks of this group appear at the surface, and it is not certain whether they exist there, as nearly all, if not all, of them must be cut out by the Red Rock Fault; but at Werrington, about 600 yards south-south-west of Audley Church, a well, according to Mr. J. Maddock, was sunk in a light brown grit, which may possibly belong to the Keele Group.

CHAPTER VII.

THE TRIASSIC ROCKS.

By W. GIBSON and C. B. WEDD.

Distribution and Classification.—The Triassic strata bordering the coalfield on the south and south-west fall into two main groups, consisting of an upper one of red marls with flags and more or less even-bedded sandstones at the base, and a lower one, made up of extremely false-bedded red sandstones, with lenticular beds of shingle and pebbly sandstone. The inferior set of rocks belong to the Bunter formation; the superior to the Keuper.

Compared with West Cheshire, the typical area of the Triassic rocks of the Midlands, the following table shows how feebly they are developed in North Staffordshire, where in fact we are dealing with the marginal representatives of the red rock formation of the Midlands.

TABLE OF COMPARISON OF THE TRIAS ROCKS OF CHESHIRE AND NORTH STAFFORDSHIRE.

	WEST CHESHIRE.*	NORTH STAFFORDSHIRE.
Keuper.	Keuper Marl.	Keuper Marl.
	Waterstones.	Waterstones and Building Stones.
	Basement Beds.	? Feebly represented.
Bunter.	Upper Mottled Sandstone.	? Absent.
	Pebble Beds.	Pebble Beds.
	Lower Mottled Sandstone.	Absent.

Even between the sub-divisions represented it is frequently difficult to draw a hard-and-fast line. Thus, in the tract around Fulford, where the basement beds are possibly present, there is no clear divisional line separating them from the Waterstones, for the latter type of sediment is found interstratified with the coarser basement beds. In the Caverswall and Blythe Bridge area the sandstones of Bunter type can only with difficulty be distinguished lithologically from those of Keuper aspect; while almost everywhere Keuper Marl and Waterstones are inseparably linked together.

* A. Strahan. The Geology of the Neighbourhood of Chester. *Mem. Geol. Surv.* (1882), p. 1.

The lithological types constituting the two groups of the Trias, however, indicate widely divergent conditions of deposition.—The false-bedded coarse sandstones of the Bunter with their intercalated beds of shingle and massed gravels indicate rapid and irregular transportation, such as would result from occasional cloud bursts, letting loose sudden rushes of water, and thereby causing floods; the even-bedded sandstones and laminated marls of the Keuper, with its beds of rock-salt and gypsum, as clearly point to tranquil deposition under water, subjected to rapid evaporation and consequent formation of beds of salt. Similar conditions, it is found, can be met with to-day only within the desert regions of the great continents; and to such arid conditions it is generally acknowledged that the Trias period belongs.*

This interpretration of the physical conditions persisting throughout Triassic times, first enunciated by Prof. Godwin Austen and since amply corroborated from a closer study of the formation than was then possible, presents a sequence of events vastly removed in character from the maritime borderland with which we had to deal throughout the Carboniferous epoch, and entails the regional elevation of the pre-existing lowlying lands. It is therefore not surprising to find that the stratigraphical relationship of the Triassic and Carboniferous rocks presents an example of complete unconformity. Thus on Endon Hill the basement beds of the red rocks repose at a very slight angle on an eroded steeply-inclined anticlinal fold of the Pendleside Series. Near Rownall the same relationship exists. Further south, at Cellarhead, they rest almost horizontally on Coal-measures lying a few yards above the First Grit, and from thence rapidly transgress over the entire Coal-measure sequence. Traced westward from Barlaston Common the Triassic outcrop, though presenting a very sinuous outline, conforms in a general degree to the Coal-measures; but this is due to the inclination of the inferior strata never being very high, and closely approximating the universal low dip of the newer formation. On the western side of the coalfield, the junction is more often obscured by superficial deposits, and when visible is generally found to be a fault.

Bunter Sandstone and Pebble Beds.

This sub-division consists, as a whole, of two principal lithological types—a lower portion of very pebbly red sandstones and lenticular beds of loose shingle, and an upper portion of red sandstones with few or no pebbles and only an occasional band of shingle. False-bedding, on a large as well as on a small

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* For information relating to arid and desert conditions of the present day the reader may be referred to the following works: Tchihatcheff, The Deserts of Africa and Asia. *Rep. Brit. Assoc.* 1882, p. 356—Sven Hedin, Central Asia and Tibet: Towards the Holy City of Lassa. 2 vols. *London.* Walther J. "Die denudation in der wüste." *Leipsic*, 1891.

For desert conditions in the past in Britain the paper by J. G. Goodchild, "Desert conditions in Britain" *Trans. Geol. Soc., Glasgow*, Vol. XI., pt. 1, 1898, p. 71, may be consulted.

scale; characterises the whole sub-division, of which the outcrop can readily be detected by the strong tendency, almost everywhere displayed, for the rock to be cut back into deep combes with intermediate rounded lobes which are so particularly well displayed round the picturesque districts of Moddershall, Maer, Whitmore and Ashley.

The sandstones are usually soft and incoherent, more particularly in the lower portion. The component sand grains betray their desert wind-born origin in the almost complete roundness of even the smallest grains, and though in many cases the material has been swept together by water action, it had first been shifted hither and thither by desert storms, and perhaps in some cases we actually meet with the original sand dune, now more or less consolidated. The shingle beds consist of more or less consolidated gravels, the pebbles ranging from the size of a cocoanut down to that of a pea, and are as a rule smooth and well rounded. When closely packed together with little or no intervening matrix they exhibit the well-known bruised and pitted surfaces generally considered to be due to mutual pressure. They consist of a variety of rocks derived from the harder beds of the older formations, the best known being a liver-coloured quartzite regarded to represent types of a far distant origin, but which can be matched by certain lower palæozoic rocks in the Midlands.

In passing from west to east the sandstones become more and more pebbly and the shingle beds more numerous, till at Cocknage they approach the Leicestershire type, where this subdivision consists of "partially consolidated quartzose gravels, which pass upwards into more or less pebbly sandstones." *

Though the Upper Red Mottled sub-division is not definitely present, this may be due to its being concealed by the overlapping Keuper sub-division. In any case it occupies a very limited expanse, and is confined to the Maer, Ashley and Oakley districts.

There are no available data for estimating the thickness of the sub-division. In the neighbourhood of Whitmore Station over 600 feet may be assigned to the Bunter, and it is doubtful if the underlying Carboniferous rocks would be penetrated at a depth of 668 feet.

In wells and borings the Bunter is generally calcareous, and much harder than near the surface or in quarries.

The red sandstones sometimes contain barium sulphate. In the wooded stream valley on the south side of Oakley Park the red Bunter sandstones contain small rounded nodules of sand, apparently cemented with barium sulphate.

At Merelake Hill, near Alsager, there are thin veins of barytocelestite, filling joints in the red sandstone and shingle beds.†

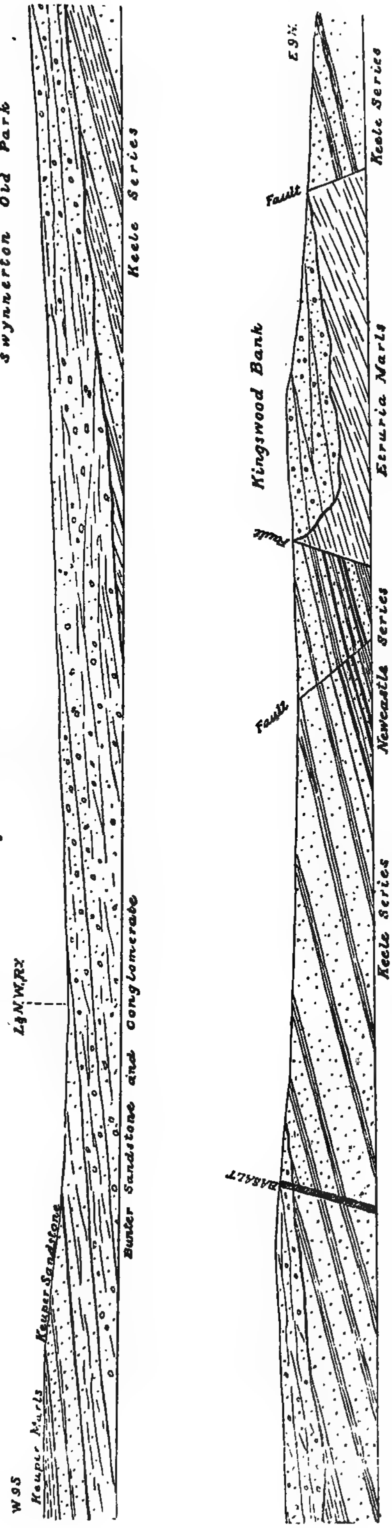
* C. Fox-Strangways. The Geology of the country between Atherstone and Charnwood Forest. *Mem. Geol. Survey* (1900), p. 32.

† Note on Barium sulphate in the Bunter Sandstone of North Staffordshire. C. B. Wedd. *Rep. Brit. Assoc.* 1899, p. 740.

FIG. 12.

SECTION ACROSS SWYNNERTON PARK AND TRENTHAM SHOWING THE MAIN SUB-DIVISIONS OF THE TRIAS.—(Scale three inches to the mile.)

By W. GIBSON.



The relation between the Bunter and the Carboniferous is one of considerable interest, as there is the clearest evidence of their great unconformity. This is admirably illustrated in the ground in the north-east corner of Sheet 123, where the Bunter sandstones capping Endon Hill have been deposited in an old Triassic valley cut in the dark shales below the Crow stones of the Pendleside Series. A small patch of Bunter sandstone also rests on the shales below the Third Grit at Rownall Hall. The junction of the Bunter with the Carboniferous is frequently very abrupt and straight. It is uncertain whether this always represents faulting, or indicates that the sandstones are banked up against the steep slopes of valleys of Triassic age. In many cases the junction can be proved to be a fault, notably in the instance of the Red Rock Fault (p. 187).

The Bunter sandstones and conglomerates are the chief water-bearing rocks of the district. The pottery towns are largely supplied by the boring at Hatton Waterworks, while that near Whitmore Railway Station supplies Crewe town and several villages and hamlets to the north. Copious springs issue from the Bunter at Moddershall and in Trentham Park.

The shingle-beds

supply abundant metal for second-class roads, and in the south-western portion of the map the harder and less pebbly varieties of sandstones have been used as building stone, but are of inferior quality. In the Maer district the brick-red non-pebbly sandstone furnishes moulding sand used in the Crewe works.

Distribution.—Brief descriptions of the local distribution and chief exposures will now be given, from south-east to south-west and then northward.

Good exposures are exhibited in the road-cuttings on the Stone road between Oulton Mill and Mostyley Mill, and again in numerous quarries and road-sections from Moddershall to the north end of Cocknage Hill. Shingle beds are very numerous.

In the Bunter tract of Creswell's Piece, where no higher rocks overlie the Bunter, it is probable that the upper part of that division is not represented, but variation of dip makes it difficult to recognise any definite sequence. Massive shingle-beds cap most of the higher ground, but along the north-western flank of the tract, where Drift obscures the junction with the Coal-measures, red and brown sandstones occur with scattered pebbles or none at all. A well at a house close to the seventh milestone from Leek showed coarse brown and light-coloured sandstone with few or no pebbles. Another, in the sharp angle between the branching roads east of Roughcote, exposed 30 feet of coarse brown sandstone with occasional thin seams of pebbles. On the east side of this tract beds of shingle appear evidently close to the base, and contain amongst the usual assemblage of pebbles occasional large well-rounded ones of purple marl, like that of the Carboniferous rocks close at hand.

To the west of Weston Coyney Hall the junction with the Carboniferous is a fault, for one is clearly visible near the tunnel mouth at Meir Station.

A long line of quarries from Normacot southward shows numerous beds of shingle interstratified with pebbly sandstones. Faulting on a small scale is very abundant. Several sections between Park Hall and Hulme show similar rocks. The junction with the Coal-measures is uncertain, but the outcrop passes obliquely across the large faults proved underground.

From Oulton Heath the Trias sends a spur northward to Barlaston New Hall. The sandstones are all excessively pebbly, and contain many thick bands of shingle. It is uncertain whether the western boundary with the Keele beds is a fault or not, though one is suggested by the high dip seen in the quarry to the north-west of Holts Barn.

The usual type of shingly sandstone is exposed along the main road from Stone to Trentham and in several quarries round Tittensor.

In Spring Valley, Trentham Park, a breccia, consisting largely of small rounded and angular fragments of a white crystalline

limestone, appears to lie at the base of the Bunter. No fossils were obtained from the limestones which resemble those of the Carboniferous Limestone Series.

The pebbles from the shingle-beds in the large quarry at the north end of Trentham Park yielded the following fossils, collected by Mr. W. Molyneux, and identified by Mr. Salter:*

Pebbles of May Hill Sandstone.—*Pentamerus oblongus, P. lens, Euomphalus sculptus, Orthis elegantula, Atrypa hemisphœrica, A. reticularis, Spirifer crispus, S. trapezoidalis, Strophomena depressa, S. compressa, S. pecten, Pterinœa demissa, Holopea, Holopella obsoleta, Palæocyclus catenulatus, Petraia subduplicata, Phacops Weaveri, Tentaculites anglicus.* Mountain Limestone.—*Poteriocrinus crassus* and others, *Rhodocrinus, Actinocrinus, Platycrinus, Lithostrotion irregulare, L. Martini, Michelinia megastoma, Zaphrentis, Syringopora reticulata, Fenestella plebeia, Phillipsia, Productus semireticulatus, P. concinnus, P. mesolobus, Streptorhynchus crenistria, Spirifer triangularis, S. bisulcatus, S. octoplicatus, S. glaber, Chonetes variolata, C. hardrensis, Dentalium ingens.*

Dr. Wheelton Hind also gives *Orthis Budleighensis,* the farthest point north and west at which this fossil has been found.

This is the best quarry in the district to show the nature of the shingle beds and their intercalation between masses of highly false-bedded loose sands or partially consolidated sandstones.

The Bunter of Trentham Park evidently occupies a hollow in the Keele Group which is here bounded by the two branches of the Apedale Fault, the eastern branch of which coincides with the slope of the Triassic valley. An isolated patch of shingly sandstone clings to the same fault to the east of Seabridge, and appears to represent the head of an old pre-triassic valley.

In the wide spread of Bunter from Swynnerton northward to Whitmore the shingle-beds hold a subordinate position, and are mainly grouped near the base. They cap the high ground, and have been quarried around Acton, Whitmore, and near Whitmore Station.

Around Maer a strong pebbly sandstone, with occasional bands of shingle, gives rise to the picturesque woodland of Maerheath and Camp Hill. The high ground of Hill Chorlton is also capped with pebbly sandstone and shingle, the latter yielding the chief road-metal of the district. The strata are inclined to the south, and the highest pebbly sandstone seen is only 250 yards from the outcrop of the Keuper sandstones. A fault, however, intervenes. At Whitmore Station the beds are inclined southwards, but to the south of Chorlton Moss they are inclined northward. A small syncline, therefore, is present under Baldwin's Gate. Around here the rocks consist of a brick-red sandstone, without pebbles; and closely resemble the Upper Mottled Sandstones of other regions. A similar brick-red sandstone

* North Staff. Field Club. Report (1887), p. 17.

underlies the Keuper of Chapel Chorlton. No definite line of demarcation, however, can be traced between these brick-red sandstones and the pebbly sandstones and shingle-beds below. The sandstones are being extensively quarried near Woodendale Farm for moulding sand, which is taken to the Crewe Works. A similar brick-red sandstone forms the picturesque wooded knolls of War Hill, Red Hill and Berry Hill. Berth Hill, however, is capped by Keuper Sandstone.

Between Loggerheads and Mucklestone a thin covering of Bunter Pebble-beds spreads right across the faintly discernible anticline. From Ashley Heath the basement beds of the Bunter form a strong feature running in a northerly direction to Willoughbridge Wells. The rising ground is composed largely of shingle-beds, which have been worked for road-metal in Scrubby Oaks Wood and in the northern part of Willoughbridge Park. Several exposures in higher beds are seen in the lanes north and north-west of Ashley, and still higher beds of slightly pebbly coarse brown sandstone are intersected in the lower road about 800 yards north of Ashley Church. In a quarry in the northern part of Ashley Heath a coarse-grained, false-bedded, buff sandstone streaked with red, and containing seams of pebbles, overlies a bed of purple marl, the junction between the two being sharp. Small pebbles of the purple marl are found in the base of the buff sandstone, the junction suggesting local erosion. This marl, however, belongs to the Bunter, not to the Keele Group, for a buff sandstone of Bunter type underlies it in the floor of the quarry. The sandstone cannot be far removed from the base of the Bunter.*

Strong shingle-beds exposed in a gravel pit at Spanheath must be close to the base of the Bunter, as are also the buff sandstones with seams of pebbles along the north side of Mucklestone Wood. At Beazley Bank, east of Mucklestone, the basal escarpment shows small terraces due to the alternate outcrop of harder and softer strata. There are good sections of shingle-beds and pebbly sandstones in the roads and lanes at Mucklestone. On the west side of the River Tern, near Norton Forge, red mottled sandstone forms a striking cliff. A little to the north, in a quarry, the red sandstone seems to pass up into brown, hard sandstones of Keuper type, while further south in a coppice opposite Oakley Hall, and to the north below Napeley Heath, soft red or mottled sandstone, apparently at the top of the Bunter, is sharply separated from coarser white or brownish building-stone of Keuper aspect.

North of Mucklestone the junction of the Trias with the Carboniferous rocks is faulted, beds of the Keele Group occupying the higher ground on the upthrow side. At the north-western end of Cowleasow the stream falls in small cascades over purple

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* This is probably the quarry near Loggerheads figured by Prof. Hull. *Mem. Geol. Survey.* The Triassic and Permian Rocks of the Midland Counties of England, p. 25

Keele sandstones, faulted against the Bunter sandstone, the latter forming the flanks of the deeper and broader part of the valley.

From Willoughbridge north-eastwards to Astoncliff the lowest beds of the Bunter make a strong feature along the west flank of the anticline, as they do in Maer Wood on the other side of the saddle. Beds of shingle, near the base of the Bunter, are exposed in a gravel pit east of Willoughbridge, while pebbly sandstones of a higher horizon are cut through in the road south of Aston. In a small pit a few yards north of the road at Hollybank coarse-grained yellow and white loose sand, close to the base of the Bunter, contains thin seams of purple marl as in the quarry at Ashley Heath.

North of Astoncliff, where the surface-continuity of the Bunter is interrupted by the Drift-filled valley along which the railway runs, the base of the Bunter makes a bold feature for a short distance until faulted against the Keele Group. Along the line of fault the feature is less distinct; but from Bar Hill House a strong escarpment, terminating northward before reaching Bower-end, indicates the outcrop of the basal beds.

At Bar Hill in quarries and in the road there are several good sections of massive pebbly sandstones with thin seams of pebbles and lenticular beds of shingle.

Further north, Bunter pebbly sandstones and shingle-beds appear from under the Drift in the hill near the Manor House and at Heighley Castle, from whence they form a conspicuous ridge as far as the peat-filled hollow of Craddocks Moss. Exposures are numerous on the hill near Manor House, at Heighley Castle, and to the north. North of the gap of Craddocks Moss pebbly sandstones are cut through by the road from Cooksgate to Shraleybrook, where the strong false-bedding has locally been taken to indicate the inclination of the strata. About 200 yards north-east of the mill, north-west of Shraleybrook, two wells were sunk for the Audley Waterworks.* The more western of these was situated on the alluvium of the stream which flows into the head of Mill Dale. It was sunk to a depth of 140 feet, at which an inrush of water took place, but a greater depth was reached by boring. The following strata were passed through:—

		Depth in feet.
Alluvium with decayed vegetable matter and hazel-nuts		—
Boulder-clay with perhaps a little sand below		—
Soft red sandstone, reached at about - -		12
Bunter	Pebble-bed at - - -	35 or 40
	Pebbly sandstone, down to -	210 or 220

Other exposures occur north of Audley, and in the stream in Wrench Coppice. The dip is always north-westerly.

The road and the railway crossing Merelake Hill exhibit fine sections of the Bunter. In the road-cutting seams of red laminated marl, two or three feet thick, separate beds of coarse

* From information supplied by Mr. F. Rigby.

red mottled sandstone containing layers and lenticles of pebbles. The sandstone contains barium sulphate. In the railway-section the lowest beds seen are soft red mottled sandstone with very few pebbles, and are on a slightly lower horizon than those exposed in the lane. Beds of shingly sandstone come in above and are faulted against soft white Keuper sandstone. Barium with a little strontium occurs in the Bunter sandstones and shingle beds (see page 140). The lowest beds visible are considered by Prof. Hull* to be undoubted "Lower Mottled Sandstone," but as this sequence of Bunter is bounded at top and bottom by faults, it cannot be certain to what horizon the strata belong. Moreover, under the valley flanking the south-east side of Swallowmoor Wood shingle-beds were proved at a depth of 120 yards.

In the absence of any record of pebbly sandstones in the bore-hole at Town House Farm, Alsager (Sect. No. 68 Appendix) it seems safe to assume that the shingly part of the Bunter sub-division was not reached.

Further north in the district of Mow Cop the juxtaposition of Triassic sandstone with Carboniferous Limestone at the Astbury Limestone Quarry, and of Bunter with a low horizon of the Coal-measures near Ley Farm, although the junction is everywhere faulted, gives some indication of the unconformity of the Trias.

The old map of the Geological Survey (87 S.W.) represents all the Triassic sandstones on the west side of the fault in this district as of Keuper age, and Green correlates the pebbly lower part of these sandstones with the Keuper conglomerate of Alderley Edge, Cheshire.† The pebbly sandstones of Mow Cop are however quite undistinguishable from the Bunter a little further south, though separable from the normal Keuper sandstones of that neighbourhood. Green himself remarked (*loc. cit.*) that the pebbly sandstones of Mow Cop were not identical in appearance with those of Alderley Edge, for he noted in the former an absence of lime, which he states to be present in the latter.

The Bunter of Mow Cop consists of buff and reddish, soft, coarse-grained sandstones with scattered pebbles, occasional lenticles of shingle with pitted pebbles at Grotto Wood, soft, loamy, red sandstones, and beds of red marl; while at Rushton, Bunter of a similar type rests unconformably on lower Carboniferous shales.

Keuper Sandstones and Waterstones.

The group consists of several more or less distinct lithological types. The highest beds are usually reddish brown marly micaceous flags (Waterstones). They are the natural passage beds to the Keuper Marl, and are incapable of separation from it. Similar flags occur at lower horizons. Fine- and coarser-grained

* *Mem. Geol. Surv.* The Triassic and Permian Rocks of the Midland Counties, pp. 41, 42.

† *Ibid.* Geology of the Country round Stockport, Macclesfield, Congleton, and Leek, p. 40,

white and brown sandstones frequently make good building stones; the different beds being separated by bands of red marl, marly sandstone, or grey marl. A few small pebbles are sometimes present in the coarser sandstones, but there is nothing like the conglomeratic basement beds of West Cheshire. With these types false-bedded red sandstones or loose sands are sometimes intercalated. No definite sequence has been determined, and it is probable that the beds are lenticular and impersistent, or change laterally.

It is difficult to make a trustworthy estimate of the thickness. In the western area it is probably between 400 and 500 feet, but is considerably less in the eastern area, and at Beech is under 200 feet, while at Mow Cop it is only a few feet thick, unless these beds are overlapped by the marls.

Barium sulphate, except in the Waterstone flags, occurs frequently as a cementing material, and is seen as star-like forms standing out in relief on the weathered surfaces, or more rarely as veins filling joints. Copper carbonate is found in the building-stones, and has been worked at Bearstone. It is interesting to note that while these minerals occur in the sandstones, rock-salt and gypsum are found only in the marls, these latter soluble salts occurring as original deposits in the impervious strata, while the less soluble copper and barium salts, perhaps subsequently introduced, are met with only in the porous sandstones.

The harder sandstones give rise to straight escarpments and long ridges between Oakley and Bearstone, in marked contrast to the softer outlines furnished by the Bunter sandstones.

Fossils are very scarce. At Fulford, Mr. De Rance records the occurrence of *Estheria minuta*, var. *brodeana*.

Local Details.—The detailed description will be confined to a record of the chief exposures and a brief discussion on points connected with the mapping.

Commencing on the east, at Meir Station, soft white and thin red and white sandstones, much broken, are faulted against the Bunter Conglomerate. The section is chiefly interesting as showing the presence of numerous faults in the Trias. In the Meir bore-hole, close to Meir Station, there is not sufficient evidence to estimate how much of the sequence belongs to the Keuper and the Bunter respectively. The bore-hole passes through a fault, and reveals no adequate representative of the thick white Keuper sandstone seen at the railway station.

Around Blythe Bridge and Caverswall there is also considerable difficulty in separating Bunter from Keuper.

The lower beds have been extensively quarried at Beech. They consist of thick red and white sandstones, separated by thin beds of marl. They were also formerly quarried at Chapel Chorlton where in an old quarry north of the Church the following section was measured:—

QUARRY IN KEUPER BUILDING STONES, CHAPEL CHORLTON.

Character of Strata.	Thickness. Ft.	In.
Brown sandstone and thin marls	10	0
Mottled sandstone, hard	3	0
Sandstone, hard and mottled at top, white below	8	0

The white variety is in great demand and much has been sent to South Staffordshire. It is not a distinct band but is only the lower portion of the mottled variety into which it graduates.

The picturesque prominence of Berth Hill is capped with red and white even-bedded sandstone forming the entrenchment of the ancient camp.

At Ashley, east of the Roman Catholic Chapel and in the road west of the rectory, the sub-division contains soft false-bedded white sandstones blotched and streaked with red. In the section near the rectory these beds are overlain by brown flags, the junction being very sharply defined.

At Oakley neither the structure of the ground nor the sequence of the Keuper sandstones is altogether clear, but certain brown and white sandstones forming distinct ridges can with certainty be ascribed to the Keuper. Though displaced by faulting, they appear to be the continuation of the strong ridges of hard Keuper sandstone at Napeley and Bearstone. These sandstones, at any rate in their lower part, are often coarse-grained, and contain a few small pebbles. It is not clear whether the grey sandy marls with thin flaggy beds, seen in a good section near a cottage opposite Mill House and south of the lodge of Oakley Park, are intercalated with the Keuper sandstones or belong to the Red Marl. Their proximity to the massive white and red-streaked Keuper sandstone on which Oakley Hall stands, and the absence of any indication of the usual brown flaggy Waterstones, suggest the former explanation. Around Oakley Villa the succession is also obscure, and some of the lines on the map must be regarded as conjectural.

Above the hard, copper-bearing sandstones, at Bearstone, with which red or grey marls and flags and beds of loose buff sand are intercalated, soft false-bedded dull red and mottled sandstone, with barium sulphate, is seen for some distance on the west side of the village, in the road to Norton-in-Hales. A fault coinciding with the Tern Valley at Oakley brings up the top of the Bunter, and apparently repeats the whole series of the Keuper sandstones on the west.

At Dorrington, west of Pipegate Station, white Keuper sandstone quarried beneath a thin covering of Boulder-clay contains partings of marl. The dip is to the west-north-west at 6 degrees. This exposure lies in a direct line with the strike of the Keuper ridges between Oakley and Bearstone. A white and brownish sandstone, with occasional pebbles, which was passed through in a well at Irelands Cross, may probably be assigned to the basal beds of the Keuper. The Keuper rocks

remain buried under Drift from Dorrington to Eardleyend, more than a mile north of Audley.

The hill of Swallowmoor Wood, which is composed of rather coarse-grained white sandstone, with very few pebbles, is here regarded as of Keuper age, though this necessitates a fault between Swallowmoor Wood and Merelake Hill, where red Bunter sandstone is on the same strike, and is succeeded by white Keuper sandstone, followed by brown flags. The railway-section shows that faults mark the junction of these rocks.

In an old quarry in Linley Wood 40 feet of very hard massive white sandstone streaked with purplish brown, and apparently cemented and veined with barium sulphate, passes up into red flaggy beds, these in turn being seen, in the field outside the wood, to underlie more white sandstone of Keuper aspect. The thick sandstone is much shattered, owing to the proximity of the Red Rock Fault. It has a very close resemblance to the harder parts of the Keuper sandstone at Bearstone, and also to that of Beeston Castle, Cheshire.

The Linley Wood rock was included in the Coal-measures on the old map, though nowhere else in North Staffordshire do Coal-measures appear on the downthrow side of the Red Rock Fault. It is now mapped as Keuper sandstone, a view which is favoured by other considerations apart from its resemblance to Keuper sandstone of other localities, and its position on the downthrow side of the Red Rock Fault. Thus it is impossible to introduce a fault between it and some brown flags and white sandstone, essentially of Keuper aspect, in the field north of it. The thick white sandstone also agrees with the local strike of the Trias. The presence of barium sulphate, a mineral common in the Trias but not seen in the sandstones of the Coal-measures, though found in the Millstone Grit; the want of resemblance to any known rock of the local Coal-measures; and the absence of any trace of carbonaceous matter, are all points in favour of its Triassic age. Moreover, the pebbly Bunter sandstone cropping out in the valley below the Keuper sandstone of Swallowmoor Wood, and there proved underground at a depth of 120 yards, is only a quarter of a mile distant from the Linley Wood rock, with a strike which would bring it under that rock.

In the boring at Townhouse Farm, Alsager (Sect. No. 68, Appendix III), it is impossible to say with certainty at what depth the upper and lower limits of the Keuper sandstone should be drawn.

Near Mow Cop, in the road to the Station, south-east of Ley Farm, flaggy Keuper Waterstones with a bed of white sandstone are seen to be faulted against the pebbly Bunter, and apparently pass up into the Red Marls. In the lane by Grotto Wood a thin bed of hard white sandstone, brown at its base, overlies the soft red Bunter with a sharp junction similar to that seen at Napeley further south. Green states that at the Astbury Quarry the

Limestone was said to abut against a sandstone similar to that worked in a quarry at Grotto Wood.* This old quarry, however, lies for the most part in pebbly Bunter.

Keuper Marl.

We have in this district only the fringe of the wide and thick sheet of Keuper Marl, which extends over so large a part of central Staffordshire, Shropshire, and Cheshire. Throughout the region under description, the Marls maintain a generally uniform lithological character, consisting of chocolate brown or red shaly marl, streaked and blotched with light green.

By an increase of sandy material they pass down imperceptibly into the Waterstones. As there is no reason to suppose that this downward change from marl to sandstone takes place uniformly at the same stratigraphical level throughout the district, it is by no means certain that the divisional line between marl and sandstone has been drawn everywhere at the same horizon. Light-coloured sandy flags, and hard pink sandy calcareous bands are abundant throughout. The marls frequently contain casts of crystals of rock-salt. Beds of rock-salt and gypsum also occur. Salt is worked at Lawton, and its presence under the Weaver Valley is attested by brine-springs.

The Waterstone-flags pass by almost insensible gradations into the marls, and the two overlap the underlying formations. This is most marked between Fulford and Moddershall, and again to the south of Beech. It is therefore frequently a matter of uncertainty whether the junction of Keuper Marl and Bunter should be regarded as a fault or as an instance of overlap.

In the south-western area the marls are almost entirely concealed by Drift, which forms the surface-features. The boundary between the Keuper sandstones and marls is in consequence mostly conjectural. In the north-western district fine sections of the Keuper Marl are exposed in the River Dane, west of the Red Rock Fault. The strata here exhibit their usual characters, and are frequently seen to contain beds and crystals of gypsum. For some distance west of the fault a north-westerly dip prevails, but further west the beds roll gently.

A considerable thickness of Keuper Marl was passed through in the upper part of the Alsager boring previously mentioned. In the Maypole Dairy Company's boring near Congleton Station 960 feet of Keuper Marl, including some drift at the top, was penetrated, without reaching the bottom of the Marl.

A section (Sect. No. 69, Appendix III) of a boring on the Howford Bridge Estate, Buglawton, Congleton was quoted by Green without comment.† The position of this boring is some distance

* *Mem. Geol. Surv.* Geology of the Country round Stockport, Macclesfield, Congleton, and Leek, page 9.

† *Mem. Geol. Surv.* Geology of the Country round Stockport, Macclesfield, Congleton, and Leek, page 41.

further east than that of the Maypole Dairy Company, and consequently nearer to the uplift of the Carboniferous Rocks. The section is mainly in the Keuper Marl; but if it is correct, the record of "black bass" and other beds in the lower part of it suggests the possible presence of Carboniferous strata at a depth of only 118 feet.

In the south-eastern district good sections are exposed in the brick-pits east and north of the Meir Pumping Station; also in the deep cutting of the mineral line to the Foxfield Colliery.

There is no means of estimating the total thickness of the Keuper Marl within this area. It is probable that the highest beds of it do not occur within the limits of the district comprised in the one-inch maps 110 and 123, though the Lias of Audlem and probably also Rhætic strata, fragments of which occur occasionally in the Drift at Betton, lie but a short distance beyond the western margin.

The Keuper Marl is used for the manufacture of bricks, etc., especially at Meir and Blythe Bridge. But the bricks produced are inferior to those made of the clays and shales of the Coal-measures.

CHAPTER VIII.

FOLDS AND FAULTS (*General Description*).

By W. GIBSON and C. B. WEDD.

The great thickness of the Carboniferous rocks shows a long period of sedimentation over the area occupied by the Pottery Coalfield. The numerous seams of coal, the bands of ironstone and thin-bedded limestones, and the great development of such fine-grained sediments as the marls and clays, point on the whole to deposition having taken place in quiet waters. On the other hand, rapid variations in thickness and the frequent intercalation of marine bands indicate unequal sedimentation consequent on movements taking place during deposition.

These are the conditions under which the Carboniferous rocks of the Midlands generally were deposited. They were followed by the greater movements which broke up and isolated the several midland coalfields, and which served in North Staffordshire to separate those of the Potteries, Cheadle, Goldsitch and Shaffalong from each other.

The folds and numerous faults are the proof of these earth movements, which were mainly completed before the overlying Trias was deposited. These later rocks were subsequently washed away from the central portions of the Pottery Coalfield, and of the former wide extension of the sheet of red rocks which still buries up the coalfield on the south and west the isolated patches at Endon, Rownall Hall, and Seabridge alone remain.

FOLDS.

Broadly speaking, the folds comprise an eastern and western anticline enclosing a central syncline. The eastern anticline trends a little west of north, the western anticline nearly north-north-east and south-south-west, with the result of giving the syncline a triangular shape, with its apex a little north of Biddulph, and the base extending from Mucklestone on the west to Moddershall on the east.

Bordering the eastern anticline lies the small syncline of the Shaffalong Coalfield, which Mr. Barrow (p. 74) likens in shape to a modern ship with vertical sides and a flat bottom.

The eastern anticline plunges abruptly under the Trias near Werrington; to the north it is continued to the valley of the Dane.

The central syncline, well defined in its central portion by the outcrop of the Red and Grey Series, narrows very rapidly in the northern portion, but in the south gradually widens out, in which direction it slowly sinks under the Trias. The western

limb is greatly elevated by the Apedale Fault (p. 165), and the trough is further broken by subsidiary folds partly disguised by faulting, the most conspicuous of these being the gentle anticline, the axis of which corresponds with the Fowlea Brook. The strata are more highly inclined on the east, where they occasionally become vertical, but gradually flatten out towards the centre of the trough. In general shape, the syncline resembles an elongated scoop—the narrowest part in the north, where the sides rapidly approach each other, and quickly bring the coal seams to the surface; the broadest part in the south, in which direction the lower coal seams become deeper and deeper.

The western anticline, faintly recognisable in the south, at Mucklestone, becomes very pronounced at Madeley Heath, and is thence continued northward in a general north-easterly direction to Harecastle and beyond Mow Cop. In the Willoughbridge valley on the south sufficient evidence exists to show that the anticlinal axis becomes slightly shifted to the east. A similar displacement occurs at Leycett, where the Hollywood Fault diverts the axis eastward for nearly half a mile. From Leycett to Butters Green the anticline remains comparatively unbroken, the direction of the axis trending a little east of north in this section. The strata are more highly inclined on the west than on the east, the higher inclination on the former side agreeing with the more rapid slope of the surface on the west as compared with the east side of the ridge. On both flanks of the anticline the highly inclined strata, when followed in the mine workings, rapidly flatten outwards from the axis. This is very pronounced on the west in the nearly vertical seams of coal known as rearers (p. 42), which from being vertical in the upper workings, rapidly flatten out westward in the lower levels. The shape of the fold, therefore, resembles an inverted vase.

North of Wood Lane, the structure becomes more complex. Between here and Kidsgrove the disturbance consists of one, and sometimes two anticlines, intersected by faults, and dislocated. It is interesting to note the close connexion of the faulting with the folding in the neighbourhood of the main anticline; the progressive easterly displacement of the anticline when traced northwards, its dislocated sections sometimes overlapping, as at Hollins Wood and Diglake; the westerly twisting of the faults as they cross the fold at its points of dislocation; and their frequent divergence and branching north-westward after traversing the uplift. The general effect produced by this successive shifting of the anticline, and the curving and splitting up of the faults which intersect it, suggests a strong lateral wrench applied to the strata in the process of folding. In connexion with this the discordance of position between the apices of radial faulting and folding further north may be noted (see p. 155).

Though the general direction of the anticlinal system across the district maintains a north-easterly course, the sections into which the main anticline is divided by faulted dislocations,

usually have a more northerly trend, the general north-easterly direction being in part due to the easterly shift.

These anticlines stand out at the surface prominently as ridges, the size of which seems to be in some degree proportionate to the intensity of the folding. Bound Hill (656 feet), Bignall Hill and Old Hill (each over 700 feet) form very conspicuous features; and the ridge on which Clough Hall stands, though not much more than 550 feet in altitude, is no less conspicuous above the generally lower ground from which it rises. On the other hand, the eastern saddle at Talk o' th' Hill, where the fold is a double one, is a smaller anticline and makes a much less striking feature. The same relationship of the slope of the surface to the inclination of the strata obtains here as in the south. Thus the steep western slope of Bound Hill coincides in position with the high-dipping western limb of the anticlinal fold, though the amount of inclination of the beds greatly exceeds the slope of the ground. This frequent coincidence of geological structure with physical feature in North Staffordshire would seem to point to the comparatively recent uncovering of the Coal-measures, the surface of the pre-triassic landscape being still partly maintained.

The folding, described above, belongs mainly to the Carboniferous rocks, but the overlying Triassic deposits are similarly involved, but in a much less degree; for though the latter are strongly unconformable, especially in the eastern area, yet in the south and south-west the folding of the Trias appears to be moulded on that of the Carboniferous rocks, as has been observed in other regions.

FAULTS.

The faults and folds, as previously stated, are intimately connected. It has been shewn that the areas of the main anticline and syncline converge rapidly in the north, and gradually open out in the southern part of the area. The faults within the coalfield follow the same general plan, radiating outwards from a focus situated in the north at the termination of the Millstone Grit ridge of Mow Cop. On the east a fault of 140 yards downthrow to the east, not seen at the surface, but proved in the underground workings to the east of Adderley Green, runs in a north-north-westerly direction. Northward, this fault enters into, and becomes indistinguishable, in the nearly vertical strata south of Milton. On the west of the coalfield a long line of dislocation, with a downthrow to the west amounting to over 700 yards at Audley, extends in a general north-north-easterly direction from Mucklestone to Audley and beyond. Thus the Coal-measures between these two dislocations are arranged in a large wedge, made up of smaller wedges let in by the large Apedale Fault, and by the dislocation stretching from Longton, through Stoke-upon-Trent to Chatterley and beyond. Within these major

wedges it will be seen that smaller wedges illustrate, in a less degree, the same structural law. The system of faulting radiating from a focus in the north is crossed by another set trending nearly due east and west, with a tendency to bend northward as it approaches, and merges into the radial system, of which the Shelton Fault affords an admirable example.

In the centre of the coalfield it will be gathered from the map that every large dislocation consists of a single fracture, but traced northward and southward each frays out and disappears in a number of smaller faults. The large Apedale Fault (p. 165), for instance, south of Seabridge, splits up into four main branches, but remains as a single fracture between Seabridge and Chesterton, and then breaks up northward into a series of minor, though still large, dislocations.

The most northerly part of the Pottery Coalfield, and of the associated tracts of Lower Carboniferous rocks, affords an epitome of the structure of the district as a whole. The alternate anticlinal and synclinal folds, into which the rocks of this region are thrown, are all gathered together northward towards a common focus, and exhibit in a small compass the fan-like arrangement of folding, which, as we have seen, spreads out southward over the whole coalfield and its neighbourhood. Of these folds, the anticlinal uplift, which brings up the Carboniferous Limestone in the Astbury Quarry, continues the Western anticline of the Pottery Coalfield northward; the syncline of the Biddulph Valley is the prolongation of the central or main basin; while the anticline of Lask Edge, extended southward, becomes the saddle which separates the Pottery Coalfield from the narrow trough of Shaffalong, itself continuous northward with the shallow syncline of Rudyard.

The radial system of faulting, coming to a focus in the neighbourhood of Mow Cop, does not affect this northern district; and it is a noteworthy fact that its focus does not coincide with that of the folds, which diverge from a point further north.* The majority of the faults here cross the folds transversely. These faults are for the most part confined each to one anticline or syncline, and die out on either side towards the neighbouring troughs or crests. Those which cross the Biddulph syncline usually have a downthrow to the south, while those cutting an anticlinal crest throw down to the north. These faults, therefore, seem to be simply lines of relief and adjustment between the several segments of folds which increase in altitude to the south, and to be contemporaneous with the folding.

Age of the different Movements.—The age of the disturbances cannot be determined with any certainty. The violent unconformity of the Trias to the Coal-measures between Normacot and Endon (p. 141), plainly demonstrates that the major portion of

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* See page 165.

the folding took place in pre-triassic times. On the other hand it is evident (p. 154) that in the south-east, south, and west, folding though in a lesser degree, but from the same direction, was re-established during and after the Triassic period. In fact, it would appear that, from the earliest geological times of which any record remains in North Staffordshire, the region has been situated on a line of weakness which lasted through Triassic times, and continued as such into the Tertiary period, if the Butterton Dyke should prove to be of this age (p. 190). It is also probable from the study of recent earthquakes that it still remains an area of low resistance.

The age of the faults cannot be determined with any great certainty, but the close connexion of the faulting and folding shows that in many cases the two phenomena are the result of the same movements, and therefore largely pre-triassic. Even the large Apedale Fault, which has the general direction of the dislocations regarded as post-triassic in date in other areas, affects the Trias much less profoundly than the Coal-measures. This is more marked in the case of the east and west faults, and is illustrated by the Florence Fault (p. 159). In the Florence workings this fault has a downthrow to the south of 250 yards, but though the quarries in the Bunter of Normacot show east and west faulting, and the same direction can be seen in the Trias in the railway cutting at Meir Station, yet their throw cannot be anything approaching this amount. Here again, then, it would seem that the movements resulting in the Florence Fault attained their maximum development during Carboniferous times, but were continued in Triassic and post-triassic times.

CHAPTER IX.

FOLDS AND FAULTS (*Detailed Description*).

Folds and faults in the Millstone Grit Series on the east side of the Coalfield.

By G. Barrow.

The anticline in the Millstone Grit Series diminishes suddenly about Werrington, and the syncline of the Shaffalong Coalfield also ends off with singular abruptness a little further east along the same line. The north and south walls of these folds are often very steep, the inclination of the grits varying from 20 degrees to the vertical, while corresponding dips along east and west lines are distinctly rare. The cause may probably be attributed to the shape of the much older hard rocks underneath. The result of working out the stratigraphy of the Highlands of Scotland makes it fairly certain that these sharp local anticlines and synclines arise from the resistance offered by the ridges composed of very old rocks, probably at much less depths than one would at first suppose. In North Staffordshire, we know nothing of the character or age of the rocks forming the pre-carboniferous floor, but its rugged character can be ascertained in the South Staffordshire, Warwickshire and Leicestershire coalfields.

The fault running north and south from Wall Grange towards Cellarhead is fairly clear along part of its course in the former area, but after passing Coalpit Ford it is difficult to trace. A fault seen in the stream at Coalpit Ford throws slightly higher beds against the basal shales of the Coal-measures, but unless the throw has greatly diminished this may be only a branch of the main dislocation. Close to the stables, Westwood Manor, a quarry in the First Grit shows the beds inclined to the east; whilst close by in an old marl pit at the foot of the hill the dip is reversed. The marls lie between the Crabtree Coal and the Shaffalong Coal, so that the fault has a throw of about 100 feet at the foot of the steep bank. How far it is continued to the south it is difficult to say; but the position of the First Grit at Cellarhead may be explained by a fault throwing down the Coal-measures of Wetley Abbey against the grit, the latter dipping to the west under the Coal-measures of Werrington

Drift obscures the northern termination of the fault, but it clearly splits up in this direction, for the Third Grit north of Wall Grange is much broken by branches of this dislocation.

On Wetley Moor, about one quarter of a mile to the north-east of Launders Bank, a fault brings the First Grit against the Third Grit, but it has been found impossible to trace it far to the north-east or to the south-west. It has evidently limited the workings in the Crabtree Coal and Two feet Coal to the south of Launders Bank situated between this fault and another dislocation running parallel with it. The latter truncates the First Grit to the north-east and south-west of Werrington. It also probably truncates the same grits to the west of Wetley Abbey, for a fault feature is clearly seen here, though its passage across the intervening shales cannot be traced. The small north-and-south fault near the Church at Bagnall is also well seen where it cuts the Third Grit; it seems to decrease to the south, for it is still less where it crosses the First Grit. To the north, however, the throw increases and produces a considerable displacement, where it crosses the grit at Stanley, before entering the shale area, where it becomes lost.

Another fault, trending north-east, passes close to Stanley, crossing Stanley Pool and on to Wall Grange. Its effect on the outcrop of the Crowstones is very clear about Hollinhurst, as these beds are locally very hard and make sharp features in the soft shales.

Faults in the Coal-measures of the Trent Valley.

By W. GIBSON.

It is uncertain to what extent faulting and folding affect the apparently regular outcrop of the Coal-measures between Hulme on the south and Milton on the north. The fault of 140 yards downthrow east proved in the Cockshead Coal south of Willot's Wood may turn to the north-east slightly and traverse the measures to the east of Ford Hayes. It most likely, in common with the other faults in this neighbourhood, maintains its north-north-westerly course and so passes under the Drift to the west of Ford Hayes. The strata flatten out on Wetley Moor, but commence to rise again on approaching the Grit Series. From Carmountside, northward, the strata are more closely packed together. In the stream, west of Little Eaves farm, a small strike fault, due south of the elbow in the First Grit at Woodhead, strongly suggests that a portion of the measures may be here cut out by faulting.

The remarkably straight outcrop of the Bunter, north of Meir Villas, suggests a fault. Such a fault, trending nearly due north and south, appears at the mouth of the Meir Tunnel, and may be the southerly continuation of the 140-yard Fault to the north. If so, a considerable portion of the chief seams underlies Weston Coyney Hall, even if the fault has largely decreased in magnitude; for the marls at Weston Sprink, of which there is some reason to believe lie above the Yard Coal, crop out on the upthrow side of the fault (p. 66.)

The narrowness of the outcrop of the Newcastle Group south of the Florence Colliery may possibly be accounted for by the fault, with a downthrow to the west, which skirts the eastern slopes of Cocknage Hill further south. In the Florence Colliery workings the faults, as yet proved, have a more westerly trend. The fault of 60 yards down west, proved in the Moss Coal, Ash Coal, and Great Row Coal, and intersecting No. 1 shaft at a depth of 323 yards, cuts out a considerable portion of the measures between the Deep Mine Coal and Bassey Mine Coal; but the hade of the fault allows the Wood Mine Coal and Cannel Row Coal to be present in No. 2 shaft.

We now come to a number of dislocations to which names have been locally attached or to which names may be conveniently given when this is not the local practice.

Florence Fault.—In the northern limits of the workings of the Florence Colliery a fault has been touched in the Ash Coal. From a comparison of the depth from the surface of the Ash Coal at Florence with the depth to the same coal in the Stone Road Colliery the fault is estimated to have a downthrow to the south of 250 yards, which agrees with the amount of throw proved in the Moss Coal at the Florence Colliery. It trends east. The fault does not appear at the surface, but the hade in the Florence workings amounts to 40 degrees, which would bring its surface position a little to the north of the Church at Normacot. It has not been proved far westward in the direction of Dresden, but a fault a little to the south of Longton Pool, west of Dresden, touched in the Ash Coal from Longton Hall Colliery, is regarded as the same dislocation, and is thence considered to turn northward in the direction of Cockster Brook. A fault with the same westerly direction has been touched to the east of High Goms Mill in the Bassey Mine Coal and Great Row Coal from Longton Hall Colliery; but further west the evidence does not countenance the idea of the fault turning north up Cockster Brook. Between Longton Lea and Blurton Tileries, and to the west, the Etruria Marls, excepting the small faulted triangle of Newcastle beds in the wood at Blurton Tileries, are at the surface from Blurton Cottages to the Tileries, while a borehole (Sect. No. 57 Appendix III.) put down on the north side of the mineral line near the eastern edge of the wood proved Etruria Marls to the bottom of the boring (390 feet); while a borehole (Sect. No. 56) 100 yards to the south, passed through nothing but Keele sandstone. A large fault, therefore, passes between the two borings. Further confirmation of the existence of this fault exists at Blurton Tileries, a short distance to the west, where red Keele sandstone appears at a spring about 50 yards south of the Etruria Marls exposed in the marl pit. The red sandstone was also found in a trench dug near the cottages west of the spring. At this point, then, the whole of the Newcastle Group is faulted out, implying a throw of at least 100 yards. The diminution in the amount of dislocation from that at Florence

may probably be in part accounted for by the fact that between Blurton and the Stone Road Colliery the fault is augmented by the Longton dislocation, which has a downthrow of 90 yards south-west.

The evidence for the continuation of the fault south-west of the Tileries up to the alluvium of the Trent is based upon the fact, that near Blurton Waste the Keele sandstone remains at the surface, while to the north there is no indication of the Newcastle Group. In following the coal seams from the Great Fenton Colliery the dip increases from 1 in 9 underneath Longton Mill to 1 in 7½ a little to the north-east of Blurton Waste, or vertically below the approximate surface position of the Florence Fault.

Adderley Green Faults.—In the workings of the Adderley Green and Rookery collieries two large faults are proved which make no indication at the surface. The easternmost is the fault proved from Adderley Green to have a throw of 140 yards down east, bringing the Hard Mine Coal on the east against the Cockshead on the west. The trend is north-north-west and south-south-east. As previously stated (p. 158), its continuation northwards can only be surmised. Two faults, 20 yards and 70 yards down north-east respectively, are proved in the Cockshead Coal west of the Rookery Pits. These faults trend north-north-west and south-south-east, apparently coming together to the south to make the fault reckoned at 90 yards touched in the Cockshead Coal beneath the fishponds at Park Hall. The faults, or one of them, evidently extend to the north between the Old Hulme Colliery and Park Hall. The surface position here coincides closely with the outcrop of the Bunter.

Longton Fault.—There is little doubt that this clearly defined dislocation in the underground workings branches from the Florence Fault, a little to the south-east of the Daisy Bank Marl Pit, Longton. It is possibly continued across the Florence disturbance, as the 60-yard Fault met with in the Florence Colliery. The surface position is everywhere concealed, but its underground course is well assured. From Daisy Bank to the junction of Heathcote Street and New Street, Longton, the general direction remains north-north-west. It then turns to a north-west course and maintains this direction to the farthest point proved. In the underground workings it is not a straight fracture, but zig-zags about in an irregular manner. The downthrow west varies between 90 and 95 yards. Its effect at the surface is most pronounced on the outcrop of the Bassey Mine, which it throws from the north end of Duke Street to near the junction of Victoria Road and High Street, Fenton. It is said to have been exposed in the north-east corner of the Daisy Bank Marl Pit. The furthest point to the north-west at which the fault has been proved lies to the north of Mount Pleasant, where in the Yard Coal, parallel with the Uttoxeter Railway, it has a throw of 90 yards to the south-west.

In the marl pits on the north of the railway the dip is persistently to the north, while to the south in the Glebe Colliery workings the inclination is a little to the south of west, showing that the Longton Fault here accompanies a gentle anticlinal uplift, probably a continuation of that at the Canal Tileries. (p. 121). Between the northern limits of the Glebe Colliery and the Shelton Colliery workings, south of Etruria, no surface or underground information can be obtained. Several powerful east and west disturbances in the Bucknall area head for the junction of the Trent River and Fowlea Brook, under the centre of Stoke-upon-Trent; and since, as shown by the Shelton Fault (p. 163), these east and west fractures tend to bend northward on approaching the Trent at Stoke, we might reasonably expect the Longton Fault to suddenly assume an increased magnitude of displacement north of Stoke. In the Shelton workings, to the north of the Newcastle New Road, a fault agreeing in direction and downthrow with the Longton disturbance has been touched in the Great Row Coal, the fracture being met with to the south of the Canal Tileries at a spot 1,062 feet below the surface. On the west or downthrow side of the fault, red marls were encountered. These are either the Etruria Marls, or the red marls below the Red Mine Ironstone. From the thickness of the marls proved by boring in the underground workings it would seem that they more likely form a part of the Etruria Marl Group. If this is correct, the throw of the fault must be over 250 yards; and it would therefore appear that the faults coming from the east join the Longton Fault in the unproved ground at Stoke-upon-Trent, and so increase the amount of throw. Even supposing the red marls to be those below the Red Mine the throw would be over 150 yards, a considerable increase as compared with the throw in the Glebe Colliery. The Canal Tileries show that the fault follows a line of anticlinal uplift which is known to be continued to the north. The section (p. 117) illustrates the structure a little south of the Canal Tileries.

Fenton Park and Ubberley Faults.—Several faults, not capable of identification at the surface, have been proved underground between Fenton Park and Bucknall. The most southerly, trending west-north-west, skirts the south end of Warrington's Marl Pit, and has been proved to have a throw to the south of 13 yards in the Ash Coal. This has increased to 40 yards to the south of Hewitt's Marl Pit, and to 60 yards in the Great Row Coal close to the margin of the Trent alluvium west of the last mentioned locality. This fault may separate the two marl pits, in which case the horizon of the coal seams in Hewitt's Marl Pit would be open to doubt. The next fault of any size is one proved to be 170 yards down south in the Bowling Alley Coal to the east of Berry Hill Farm. It has also been determined in the Moss, Ash, and Spencroft coals to have an irregular but general east and west trend. Its surface position is a few yards to the south of the old Brookhouse Colliery, and probably

causes the high inclination seen in the stream at the south end of the refuse heap of the New Ubberley Colliery. It may be called the Ubberley Fault. Between these two faults the strata are crossed by a great number of smaller faults. It will be noticed that these dislocations point, on the one hand towards the disturbed area in the Shelton workings, and on the other towards the locality where the anticline in the Grit Series suddenly terminates on the south between Wetley Abbey and Werrington.

Another east and west fault has been touched in the Ten Feet Coal, 100 yards south of the old Mossfield Colliery. The throw has not been proved, neither can its surface position be detected, owing to the covering of Drift; but there can be little doubt that it coincides with the east and west valley, and is probably the westerly prolongation of the dislocation seen in the Grit Series to the east. That the throw is to the south may be gathered from the Ten Feet Coal cropping out on Bucknall Hill, while it is 170 yards deep in the shafts of the New Ubberly Colliery, situated along the line of strike with respect to Bucknall Hill.

Northwood and Whitfield Faults.—A fault trending north-east and south-west has been touched to the north-west of Birches Farm, but the throw and direction have not been proved. Between here and Black Bull, the eastern margin of the coalfield remains remarkably free of dislocations, agreeing with the nearly unbroken outcrop of the First Grit, but the strata have been subjected to considerable pressure, resulting in the local over-thrusting of one bed over another. In the Whitfield Colliery the Holly Lane Coal and Ten Feet Coal are thus duplicated by a small thrust fault.

North and South Fault.—This springs from the Shelton Fault (p. 163) near Mousecroft, Hanley, and has been proved at intervals to a little north of Fegg Hayes, keeping a nearly meridional course along the whole of this line. It commences in the centre of Hanley with a throw in the Ash Coal of 22 yards down west; this increases to 100 yards in the workings of the Pear Tree Pits, but decreases to 90 yards in the Sneyd Colliery, and diminishes to 55 yards in the Burnwood Coal in the Highlane Colliery; while north of the Chell Colliery it appears to split up into two faults of 12 yards and 38 yards respectively. As the course of the fault closely coincides with the general strike of the Coal-measures, few indications of its surface position exist; but it is intersected by the mineral line from the Whitfield Collieries to Pitts Hill. In the vicinity of the fault the strata are much compressed, and a thin coal has been drawn out into thin shreds and streaks. This phenomenon is repeated at the junction of some nodular shales and a massive yellow grit 40–50 feet distant from the fault. What was evidently a thin seam of coal has here been torn up by the movement into small star-like forms, three-quarters to two inches across, round which the shales have moulded themselves.

Shelton Fault.—From Hanley to Etruria Vale this fault, with a throw of 40 yards down south, trends nearly east and west; but a little to the east of Etruria turns sharply to the north. The hade is much greater in the lower seams than in the higher (Fig. 11, p.117). There can be little doubt, though not absolutely proved by workings, that this fault joins the Longton disturbance north of Etruria before the latter splits to form a system of faulting now to be described.

Bradwell Wood and Brownhills Faults.—The Bradwell Wood Fault has been proved in the upper ironstones from a little south of the old Alum Works to a little to the east of the High Carr Tileries. To the east of Bradwell Wood it is estimated to have a throw of 100 yards down south-west in the upper ironstones. Its surface position here is not seen, but it becomes very marked to the north-west by the shift in the position of the outcrop of the Etruria Marls and Bassey Mine. North of the outcrop of the Bassey Mine the surface position corresponds very closely with the stream valley to the east of the High Carr Tileries; and is the fault considered by Mr. Wedd to reach the surface a very short distance north of the Jamage mineral line. It was probably the fault encountered in the Burnwood Ironstone close to the crossing of the roads to Newcastle and Chatterley. On the opposite side of the valley a nearly north and south fault of 80 yards westerly downthrow has been proved in the Red Mine of the Brownhills Colliery. What is the course of this fault to the north is uncertain; but its surface position agrees with a dislocation crossing the Etruria Marls east of Brownhills, and which can be traced northward into the marl pit near Sun Street, Tunstall, where it appears to be on the point of dying out.

Sneyd Fault.—This is a small east and west fault extending from the viaduct near the Cemetery to the Town Hall, Burslem, where it terminates. Though having only a few yards throw, it appears to affect all the seams. South of the Burial Ground the throw is four yards down south, which 400 yards to the west has increased to 11 yards.

Pitts Hill Fault.—This is a small fault throwing down to the north and trending due east and west. It probably continues to the west of Pitts Hill as the small fault between the Greenfield Colliery and the north end of Tunstall.

Oldcote Fault.—A nearly north-and-south fault with a considerable downthrow to the east has been proved from Aldery Lane, to Golden Hill. South of this point it is not recognised, but the shift in the outcrop of the Red Mine north of Holly Wall necessitates a fault which would fall in a line with the Oldcote disturbance. In the Burnwood ironstone near Oldcote Farm the throw has been proved to be 90 yards. In the Bowling Alley Coal and to the east of Whitehall, this has decreased 80 yards. A little to the east of the Oldcote Fault

at Golden Hill another fault with a westerly downthrow has been proved in the upper seams in the Clanway Colliery. A small trough is thus included between the two faults.

In the Kidsgrove area, the Oldcote Fault is said to mark the division of the coking coals on the west from the non-coking seams on the east.

At the bend of the syncline at Newchapel a small overthrust fault duplicates the Burnwood Ironstone. The presence of an overstep fault might have been expected, as the measures in this neighbourhood and to the north have all the appearance of having been wrenched in a north-easterly direction.

Kidsgrove Faults.—Several small faults, having a general north-north-westerly trend and with a downthrow to the west of 30 to 50 yards, have been proved underground to the west of Kidsgrove. One of 50 yards has been proved in the Rough Seven Feet Coal at the north end of Bath Pool, and in the Knowles Coal a little to the north of Line Houses. As the Knowles Coal crops out a few yards to the north of the underground position of the fault, the latter must cross the Harecastle Tunnel between Line Houses and the northern end of the long tunnel.

It is noticeable that whereas the Kidsgrove Faults have all a westerly downthrow, the majority of those to the west have an easterly downthrow. Thus the structure of the ground consists of a series of troughs let down one within the other.

Ravenscliff Fault.—This trends north-north-west and south-south-east and has a downthrow to the south-west of 30 to 50 yards. It is visible near the tunnel mouth north of Chatterley Station, and then strikes for Ravenscliff House, near which it shifts the outcrop of the Bassey Mine Coal 200 yards to the south-east. It is locally considered that north of Ravenscliff the fault turns northward, and becomes the fault of 50 yards at the north end of Bath Pool. This identity has not been proved, but it may be possible that the Ravenscliff Fault quickly dies out north of Ravenscliff House, and its place be taken by the 50-yard Fault.

Newcastle or High Carr Fault.—A clearly defined dislocation trending north-north-west and south-south-east which has a large downthrow to the east. Although never visible at the surface its position can be determined with considerable ease by its effect on the outcrops of the various sub-divisions of the Red and Grey Group. It reaches its maximum between Hanford and Newcastle-under-Lyme, where its throw can be estimated to be over 150 yards. South of Hanford its exact surface position cannot be proved, but as it here has a throw of over 100 yards it probably continues towards Ash-green, and if it keeps its general direction would pass about half a mile to the west of the Newstead boring. Between Brampton and Bradwell Hall the fault cannot be traced in the Keele sandstone, but it gives rise to a conspicuous break in the escarpment to the east of Bradwell Hall. Northward it becomes known as the High Carr Fault. It

has been touched in the Red Shagg Ironstone, 600 yards north of the shafts of the Park House Colliery, where it is estimated to have a throw of 110 yards, which diminishes to 90 yards a little further north, where it is described in connexion with the faulting of the northern part of the anticline (p. 184).

Apedale Fault.—This constitutes the chief dislocation of the coalfield and exerts a very marked effect on the topography and economy of the district. Owing to the great magnitude of displacement a wide strip of the red and grey barren coal-measures has been wedged in between the richly productive eastern and western portions of the coalfield. It thus happens that the residential town of Newcastle-under-Lyme, and the pastoral scenery surrounding it, lies between two busy mining districts with their pit banks, head gears, and slag heaps disfiguring the landscape.

The line of dislocation can be traced continuously from Apedale to the southern margin of the map, a distance of over nine miles. The direction, north-north-west and south-south-east, remains constant, but several branches are given off on either side between Seabridge and Hanchurch. The throw attains its maximum near the Apedale Ironworks, where it brings a considerable thickness of the Keele beds against the Bassey Mine coal, from which the throw can be calculated to be at least between 600 and 700 yards. The branch faults between Seabridge and Hanchurch are inferred from the juxtaposition of the Keele Group on the east with the Etruria Marls on the west. A little north of Butterton New Farm, it would appear that a main branch proceeds to the south-east and throws the Keele sandstones of Trentham Park and the ground to the north, against the Etruria Marls to the east of Butterton New Farm. Between Hanchurch and Beech little evidence exists for determining the position of the main line of fracture; but at Beech the Keuper Marls of the Trias are faulted down on the east against the Bunter sandstone of the same formation on the west. This does not necessarily imply any magnitude in the throw, for in the southern part of the area the overlap of the Keuper on the Bunter Formation is an assured fact.

North of the Apedale Ironworks the amount of throw near Sladderhill Colliery can be calculated to lie between 360 and 400 yards, for the Etruria Marls of Chesterton are brought close to the horizon of the Four Feet Coal. Further north the fault splits up into several branches (p. 180).

Folds and Faults in the Biddulph Valley and Neighbourhood.

BY C. B. WEDD.

Folds.—The folds, in order from west to east, are the Western or Staffordshire anticline, running north-north-east through the south end of Mow Cop and the Astbury Limestone Quarry; the syncline of the Biddulph Valley with its axis lying in a slightly

more northerly direction; the anticline of Lask Edge trending almost due north and south; the shallow trough of the Rudyard syncline lying in a north-north-west direction; an anticline, probably in part faulted out, along the valley of the Rudyard Reservoir; and a syncline with north-westerly course east of this valley.

The anticline of Gun Hill, and the syncline west of it, both trending north, belong to another group outside the district. Of the folds of this district the strongest are the Western anticline and the Biddulph syncline. The complete sequence of beds exposed between crest and trough at points, as far as can be seen, equidistant from the focus of folding, affords a fair measure of the comparative magnitude of the folds. If the Western anticline and the Biddulph syncline are taken together as one unit they are seen to involve at the surface the whole thickness of strata from the top of the Carboniferous Limestone to approximately the middle of the Grey Series of the Coal-measures. If the Biddulph syncline and the Lask Edge anticline are taken as one fold, they embrace beds from the same horizon of the Coal-measures down to one but a little below the group of Crowstones. Lastly, if the Lask Edge anticline and the Rudyard syncline are taken together, they exhibit only strata from the last-named horizon up to the top of the Third Grit; while the most easterly fold is evidently also small.

The above estimate of the amount of strata, viz., from the top of the Carboniferous Limestone to the middle of the Grey Series, involved in the fold at the surface between the crest of the Western anticline and the trough of the Biddulph syncline, holds good for a transverse line between the Astbury Quarry and Bradley Green. But further north, in the neighbourhood of Mossley, the strata crossed by a parallel line from crest to trough would comprise only beds from a horizon between the Limestone and the Millstone Grit up to one but little above the Crabtree Coal. Consequently the fold is diminishing in altitude northwards and increasing southwards, a conclusion to which the northerly convergence of the axes of the folds, the narrowing of the synclines, and the continuity of the grit-outcrops around the northern ends of the basins, also point. Hence the southerly lowering of the floor of the Biddulph syncline, as shown by the increasing depth of the coals, is due to a real increase of altitude in the fold and not to a mere downward pitch to the south.

To a less extent and within narrower limits the same southerly increase of altitude appears to apply to the other folds.

The strata have a rather high dip off the Western saddle on either side—a dip which in the eastern limb increases somewhat towards the axis of the Biddulph syncline, sometimes to as much as 65 or 70 degrees, occasionally more. The westerly dip in the eastern side of the basin is much less. Consequently the axial plane of the syncline is not vertical, but inclines to the west. Hence also the axis of the trough is much nearer to the crest of the western anticline than to that of the eastern saddle of

Lask Edge. In fact the outcrop of the Eight Feet Bambury Coal, where it bends round sharply in the syncline at Gillow Heath, is about three times as far from the outcrop of the Millstone Grit on the east of the valley as from that on the west. The level course in the Newpool (Eight Feet Bambury) Coal at the Bradley Green Colliery, beautifully illustrates the regularity of the Biddulph syncline. The altitude of the fold, which as explained above increases southwards, can be estimated approximately along a line from the crest of the limestone-dome at the Astbury Quarry to a point where the trough of the syncline in the Eight Feet Bambury Seam reaches the surface near Gillow Heath. By calculating the probable thickness of strata, and allowing for any difference of height between these two points, it is found that the vertical distance between trough and crest in one bed is probably about 3,300 feet.

The angle of the fold, as shown by the outcrop of the grits in the north, and by the Eight Feet Bambury Coal, both at the surface and in the level course, is a sharp one ; but south of Bradley Green it broadens and becomes more obtuse, as is indicated by the position of the higher sandstone beds which appear through the drift-covering.

The striking difference in appearance between the two eastern synclines on the one hand, and the Biddulph syncline on the other, is due to the shallower nature of the former two, and to the fact that in them thick beds of Millstone Grit at and close to the surface are nearer to the trough of the folds than around the deep depression of the Biddulph Valley, so that lower parts of these folds are represented by hard strata at the surface, and stand up in relief as shallow elevated basins of massive grit.

The Lask Edge anticline appears to have a depression on the east side of its main crest, and to be in reality a double fold for part of its course south of Dingle Brook.*

It sinks to the south near Werrington, the outcrop of the Millstone Grit coming on in that direction and passing in turn under Coal-measures beyond the limit of this district.

Faults.—It might be expected that a district like this, where all the folds of the Pottery Coalfield and the neighbouring tracts are gathered together towards a common focus, would throw some light upon the system of faulting, if the faults and folds had a common origin. The faulting, apart perhaps from the Red Rock Fault, conveys the impression that it is the natural concomitant of the local crumpling of the strata into their fan-shaped system of folds. The Red Rock Fault on the other hand may be of more regional importance, limiting either the elevation of the Carboniferous tract or the depression of the Triassic plain.

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* The Horizontal Section on page 25 gives some indication of this.

The majority of the faults form a group transverse to the folds and ranging north-west to south-east in the west; west to east; or west-south-west to east-north-east in the east.

As has been stated already (p. 155), these transverse faults are usually confined, each to one anticline or syncline. They seem to be for the most part simply the expression of local relief and adjustment in folding, which increases in altitude southward; and to be the direct effect of this increasing of altitude of folding. If this be the case, they should die out from trough to crest with southerly downthrow, or from crest to trough with downthrow to the north.* Nearly all the transverse faults fulfil these conditions. We may express this relief and adjustment by faulting in another way by saying that while in an unfaulted fold the progressive increase of altitude in a given direction would be continuous and more rapid, the faults mark successive steps in the growing intensity of folding, by relieving the abruptness of its increasing altitude, and by adjusting to one another areas of greater and less mean vertical distance between crest and trough.

A glance at the one-inch map (sheet 110) shows that the anticlinal ridge of Lask Edge has only been dislocated in one place south of Dingle Brook; that the grit-outcrops of Mow Cop, Congleton Edge, and Rainow Hill are comparatively unbroken by faults; that such faults as do cut them are for the most part of small throw; † that more numerous faults with appreciable displacement cross the grit-ridges of the eastern limb of the Biddulph syncline; and that several faults of some importance are proved in the Coal-measures of that syncline. It is recognised by miners in the Biddulph Valley that the faults there die out westwards towards the grit-ridges. It is equally certain that these faults die out eastwards towards the eastern anticline.‡

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* This may be demonstrated by folding two sheets of paper in such a way that the folds of the one are larger than the folds of the other, and by trying to fit the ends of the two sheets together.

† Of course, owing to the much lower dip in the eastern limb of the Biddulph syncline, a comparison of lateral displacement of outcrops is no criterion of the relative magnitude of faults on either side of the fold. In the western grit-ridges, where the average dip is probably about 40 degrees, the downthrow would be slightly less in amount than the small lateral displacement.

‡ Green states, on the authority of Mr. Bradbury (*Mem. Geol. Surv.* Geology of the Country round Stockport, Macclesfield, Congleton, and Leek, p. 71), that faults which cross the basin die out in the "flats," *i.e.*, in the gently-dipping measures of the eastern side of the valley; but in the same sentence it is also stated that these faults have their greatest throw in the "rearers," the highly inclined strata of the western side. If by this it is implied that the faults continue to increase westward beyond the trough this is contrary to experience, and is negatived most emphatically in the case of the largest proved fault which crosses the trough by the almost unbroken grit-outcrops of Congleton Edge and Mow Cop.

Thus it becomes apparent that many transverse faults which reach their maximum in the Biddulph Valley have died out before reaching the neighbouring anticlinal crests.

Moreover, while the great majority of faults in the Biddulph syncline have, as might be expected, a downthrow to the south, all those which are known to cross the Lask Edge or Western anticlines throw down northward.

In only one or two cases at the most is it likely that a transverse fault crosses both trough and crest, while the mapping shews that in most cases such faults must be confined to one syncline or anticline.

This limitation of individual transverse faults to one anticline or syncline is in itself further evidence that the folds are really increasing in altitude; for if the latter were constant, and merely pitching in a given direction, there is no reason why transverse faults should not cross several folds.

Of seven faults, of which the direction of downthrow is proved underground in the Coal-measures of the Biddulph Valley, five with various amounts of displacement throw down to the south, and two to the north.* Of a total of 21 transverse faults (three of which may be parts of the same faults in different localities), either proved in the colliery-workings, or observed at the surface in the Biddulph Valley, or in the grit-ridges which surround it, 15 either have a southerly downthrow, and fail to cross an anticline, or have a northerly downthrow, while situated on or near an anticlinal crest and showing no sign of crossing the trough of the syncline. Of the remainder it is impossible to say whether two or three should be regarded as originating in the anticline or the syncline, while two or three more, including that at Biddulph Park, certainly cross the syncline with northerly downthrow.

Two transverse faults, which cross the trough of the Rudyard syncline and apparently die out before reaching the crest of the Lask Edge anticline, have a northerly downthrow. The circumstances are however different, as the same grit-beds, which lie deep below the surface in the trough of the Biddulph syncline, are at a much greater height in the trough of the Rudyard basin at an equal or greater distance from the focus of folding. Hence it is evident that this basin has not thus far the southerly declination of the Biddulph syncline. The uniformly narrow width of the fold, as indicated by the parallel outcrops of the same grits as far south as the Shaffalong Coalfield, suggests that it has been wedged in and unable to sink in the same way that the broadening Biddulph syncline did, and shows that in this part of its course the fold is not increasing in altitude southward.

* Unfortunately some doubt exists as to the throw of two of the faults at the Bradley Green Colliery, but it is certain that they throw in opposite directions.

A small group of north-westerly faults, near Rushton, has a longitudinal rather than a transverse relationship to the folding, but does not enter the northern part of the coalfield.

Local Details.

Folds.—The crest of the Western anticline can be seen in the south end of Mow Cop, on the west side of it, near Mount Pleasant, where the beds of the Third Grit (see footnote, p. 35) dip away east and west. The crest of the fold is occupied by a belt of crushed rock, closely jointed in a north and south direction, the joints being filled with thin veins of barytes. The Millstone Grit does not appear again to the north on the west side of the fold, being evidently thrown down by the anticlinal fault (see below). A ridge of Crowstone below the eastward-dipping grits runs north from here by Rode Close, where there is a small disused quarry on the south side of the old mineral tramway. Little can be seen in it now, but Mr. Branson states that both easterly and westerly dips were formerly visible, showing that the crest of the fold passes through the quarry. Northward from here the steep western slope of the high ground is obscured by thick woods nearly as far as the old Limestone Quarry south-east of Astbury. In the upper part of these woods the beds of Crowstone, with eastward dip, often form strong, but generally impersistent features, swerving to north-north-east and north-east as they approach the Limestone Quarry. One of these, however, along the top of Hanging Wood continues unbroken for nearly a mile and a half, and shows that no transverse fault can be drawn here.* In the lower slopes of these woods the sandstone features have a north-westerly dip, often as much as 30 degrees or more. In the Astbury Limestone Quarry the crest of the fold becomes evident (p. 22), bringing up the Carboniferous Limestone in a quâquâversal dome. It will be seen that as we approach the limestone from the south, the outcrops of the grits diverge continually further east in the eastern flank of the fold to let in the intervening beds of lower shale.

Faults.—Mow Cop Boundary Fault.—Some uncertainty exists as to the position of an important fault which brings the Coal-measures against the Pendleside Series on the west side of Mow

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* At St. Thomas' Church, Mow Cop, Green (*Mem. Geol. Surv.* Geology of the Country round Stockport, Macclesfield, Congleton, and Leek, p. 70) notes a "very sudden change in the arrangement of the measures" from a simple easterly dip in the north to a saddle in the south, and postulates a transverse fault to account for it. The change is no more than must take place, when beds in anticlinal form, previously occupying the crest of the fold, diverge, as lower horizons in the fold are brought to the surface. The western outcrop of the grit is thrown down by the fault bringing in Coal-measures on the west, and no transverse fault is needed.

Cop. It is probable that it starts along the anticlinal crest at the south end of the ridge, and developes a stronger westerly downthrow as it travels northward. It appears to continue almost due north, as it approaches the point of greatest uplift in the fold at the Astbury Limestone Quarry. That a fault having a large westerly downthrow, and trending nearly north and south, exists here is obvious for the following reasons:—The Millstone Grit is missing on the west flank of the anticline, except at the south end of Mow Cop; beds of the Coal-measures and of the Pendleside Series, both with westerly dip, lie upon the same strike on the west flank of the fold; while on the east side the almost unbroken outcrops of Millstone Grit and lower strata, dipping east, shew the impossibility of a transverse fault of the necessary amount of throw.

The beds exposed in the lower slope as far north as Grotto Wood* have all the appearance of Coal-measures, rather than of strata below the Millstone Grit, particularly a pebbly grit which strongly recalls that below the Crabtree Coal in the Biddulph Valley. This view is in harmony with the outcrop of the Winpenny Coal north-east of Hall o' Lea. The features upon the lower slope all die out northward at Grotto Wood, while a short distance further north the strata certainly belong to the shales above the Limestone.

It seems then highly probable that this boundary-fault between Coal-measures and Lower Carboniferous strata approximately coincides with the crest of the anticline as far as the north end of Hatching Close,* and then swerves slightly down the western flank of the fold towards the Red Rock Fault, which it joins between Grotto Wood and the Astbury Limestone Quarry.

The 280-yard Fault at Hall o' Lea.—A large north-easterly fault, with a downthrow estimated at 280 yards to the south-east, is proved at the Hall o'Lea Colliery in the Four Feet Coal, at a depth of 140 yards; at this depth it passes a little more than 20 yards east of the shaft to the Seven Feet Bambury Coal on the south-west side of the brook. The fault is said by Mr. Branson to have a hade of only 36 degrees. From its direction it evidently belongs to the radial system of faulting.

Transverse Faults.—East of the Hall o'Lea Colliery, according to Mr. Branson, a fault running east and west with a northerly downthrow of about 80 yards, throws the outcrop of the Bullhurst Coal on the north side of Mow Lane against that of the Eight Feet Bambury further north.

A fault running west-north-west has been touched at the same Colliery across the strike of the highly inclined measures in the Two Row and Seven Feet Bambury coals, half-way between the colliery and The Bank; it has a southerly downthrow believed

* Grotto Wood is the lower north-western limb, Hatching Close the higher south-eastern part, of the woods, which cover the west flank of Mow Cop.

to be about 70 or 80 yards. Close to a sharp bend in a footpath which runs south across the old tramway and along a valley between the outcrops of the Bambury and the Bullhurst coals, a shaft was sunk upon a fault, evidently that described. It brings the outcrops of the Seven Feet and Eight Feet Bambury coals close together. A little further south there are indications of another small fault in the same direction.

It may be expected from its position in a narrow tract between the Red Rock Fault and the Western anticline, and from what is known of the ground in a similar position further south, that this locality is broken up by numerous other faults, not yet proved.

Two or three small faults with northerly downthrow cross the outcrop of the Grits on Mow Cop, and either traverse the anticline or terminate against the Mow Cop Boundary Fault.

From here, as far as Black Cob at the north end of Chesham Close, the escarpments of the two Millstone Grits, and also of the small pebbly grit near the Crabtree Coal, are not displaced. It may be noted in passing that the direction of a fault with a proved downthrow of 45 yards in the syncline at Bradley Green heads for the middle of this length of unbroken escarpments, which it may reach, but could only cross as a very small dislocation.

Northward no faults cross the grit-escarpments till we reach the gap at Mossley. The presence of this wide gap is evidently connected with faulting; yet the total displacement cannot be great. It appears to be crossed by two or three faults, of which the net result must be a downthrow to the south between Congleton Edge and Rainow Hill.

Bridestones Fault.—A fault having clearly a downthrow to the north enters the syncline from east-north-east and produces a considerable displacement in the Third Grit at Bridestones at the south end of The Cloud. It dislocates also the First Grit, and the thick sandstone below the Little Row Coal.

Further south an east-and-west fault at Biddulph Park, with northerly downthrow, displaces both Grits, and the higher sandstone above-mentioned, as does also a third fault, in a west-north-west direction still further south, between Newtown and Troughstone Hill. It has a southerly downthrow, the broken escarpments suggesting an increase of throw westwards.

These three faults all converge towards the Mossley gap: and if they cut the outcrops of the western grits at all, they must do so here. Now if these faults keep the same amount of throw which they severally seem to have where they dislocate the eastern grits, the joint northerly downthrow of the two northern faults might be expected to exceed the southerly downthrow of the southern fault, and produce a net downthrow to the north in the Mossley gap. But it has been stated that the net downthrow in this gap is to the south. Consequently it is probable that, of

the Bridestones Fault and that at Biddulph Park, one or both diminish or die out westward before reaching the western grit-escarpments. There is no evidence that the former of them crosses the trough of the syncline, though the latter is probably one of the very few faults which do so with a northerly downthrow.

Another fault appears to cross Cheshire Brook at a point east of Hindswood, where a very high south-easterly dip gives place to a gentle south-westerly one in the bend of the fold. Here the horizons of the Crabtree and Little Row coals are thrown against that of the First Grit on the north, so that the fault must have a downthrow southward. It appears to be in the same direction and nearly in the same line as the Bridestones Fault, with northerly downthrow, which therefore seems to die out without crossing the trough.

The fault at Troughstone, with southerly downthrow, clearly does not cross the eastern anticline; but there is reason to believe that it crosses the trough of the syncline with increased displacement.

Spring House Fault.—Further south, in the deep gorge through which the stream flows at Spring House, there is good evidence of a fault running north of west, a sheer wall of the Third Grit being strongly "slickensided" and brought opposite the base of the First Grit. The pebbly rock near the Crabtree Coal is repeated in the stream, which swerves across the fault. The downthrow is clearly to the south. The increasing westerly dislocation of the outcrop shews either a westerly increase of throw, or a decrease of dip in that direction, probably both. North-east of Biddulph Grange, a shaft 100 yards north-east of the stream is stated to have been sunk on a fault, evidently the Spring House Fault. It seems impossible that this fault can cross the eastern anticline; but it is quite likely to be continuous with a small fault on the west side of the Biddulph syncline, where the grits are displaced west of Beacon House with greater dislocation of the First than of the Third Grit. If not, it does not cross the western grits at all. It is a good instance of a fault with southerly downthrow reaching its maximum in the trough of the syncline and dying out east and west towards the neighbouring anticlines.

At Outwood Gate a west-north-westerly fault with small displacement produces less dislocation of the Third than of the First Grit, either by westerly increase of throw or decrease of dip. Its downthrow to the south seems to be still greater westward where it cuts the Crabtree Coal. The pebbly rock below that coal, seen in the stream east of Biddulph Grange, makes a small feature which runs to Woodhouse; south of which, near the road, an old shaft reached the Crabtree Coal, dipping about 20 degrees west at a depth of 70 yards. The fault passes north of the shaft, for on the south side the

outcrop of the Crabtree lies a good deal further east. The fault cannot cross the eastern anticline.

The Crowborough Fault.—This dislocation crosses the eastern anticline in a direct east and west line north of Crowborough and Hollins. South of the stream occupying the fault-valley at Sprink, a broad ledge of swampy ground, in which the features from the south end off, indicates the belt of fracture; while in the stream the crowstones are shattered and twisted. North of the fault a group of these crowstones, dipping east in the east flank of the saddle, makes a bold feature between Broadmeadows and Shirkley Wood; while south of the fault the same crowstones are shifted to the east in Cliff Wood. It seems that the fault cannot continue much further to the east, for there is no adequate break in the grits of the Rudyard basin. West of the crest of the fold the outcrop of a grit, with westerly dip, terminates at Crowborough, while the outcrop of the Third and First Grits, the sandstone below the Little Row Coal, and Crabtree Coal, are all displaced westward on the south side of the same line. West of the Crabtree outcrop the fault could not be recognized at the surface.

At Newpool, a small fault running nearly east and west in the Newpool Coal has a southerly downthrow which is proved to increase westward towards the trough to 4 or 5 yards.

Folds and Faults in the Western Anticlinal Region.

SOUTHERN PORTION BY W. GIBSON.

Anticlinal Fault.—Considerable uncertainty exists about this dislocation, to which it is convenient to give this name by reason of its rough parallelism and nearness to the axis of the anticline between Apedale Hall and a little north of the Silverdale Ironworks. Along this line its course keeps nearly north and south; but at the Silverdale Ironworks it would appear to swerve to the east, and to join the Hollywood Fault a little to the south of the Kentslane Colliery. Four hundred yards to the west of the Wellfield Pits its throw has been estimated at 90 yards down east in the Ten Feet Coal, and 80 yards in the Four Feet Coal 700 yards to the south, and the same amount of throw in the Little Mine Coal beneath Silverdale House.

Hollywood Fault.—This can be traced from the south-eastern end of Craddocks Moss on the extreme western margin of the coalfield to Silverdale Farm on the east, where it joins the Anticlinal Fault. The course is nearly due east, and west, and the downthrow to the south. In the Ten Feet Coal of the Hollywood Pit workings the amount is 180 yards; in the Leycett workings it varies from 190 to 210 yards. After joining the Anticlinal Fault at Silverdale Farm the line of fracture is continued in a south-east direction till it meets the Apedale Fault to the east of the Cloughs. The Anticlinal and Hollywood faults throw down in

opposite directions; they therefore tend to neutralize each other, but to what extent has not yet been proved, the throw of the faults near their junction being unknown.

It is not certain if the Hollywood Fault affects the Trias, but a slight break in the outcrop of the base of the Bunter Conglomerate can be detected to the south-east on the south of Craddocks Moss.

Another fault of 70 yards down south has been proved in the Rough Seven Feet Coal, 200 yards to the north of the Hollywood Pits; and would appear to be the easterly continuation of the 72 yard Fault proved in the Bullhurst and Four Feet seams to the north of the Wood and Harrison shafts of the Madeley and Leycett Collieries.

Dunge Wood and Ridgehill Faults.—Between the Hollywood Fault and Madeley Heath the ground exhibits a complex structure, the principle of which has not been elucidated owing to the absence of clear sections. A north-north-west and south-south-east fault has been touched in the Great Row Coal, 400 yards to the east of Finney Green Farm. It is said to throw down to the west, but whether it is a small or a large fault has not been ascertained. Red sandstones and marls of the Keele Group appear to be thrown down on the east in Dunge Wood against the Etruria Marls seen in the north end of the railway tunnel. The base of the Etruria Marls appears also to be shifted to the north of Finney Green. The whole ground, however, is very obscure, and unfortunately the records of the borings (Sects. Nos. 63–65, Appendix III) do not render much assistance.

A fault, trending north-west and south-east, crosses the marls in the Ridgehill Brickworks; and on the same line to the west a fault, with an apparent downthrow to the north, dislocates the small anticline seen in the south-western corner of the Madeley Heath Brickworks.

The narrowness of outcrop of the Black Band Group north of the Madeley Heath Brickworks strongly suggests a fault, but this cannot otherwise be demonstrated.

The Western Boundary Faults.—Surface observations and mining information render it certain that along the whole western margin of the anticline a line of powerful fracture extends from Mucklestone to a little west of Harecastle. The fracture does not consist of a simple dislocation, but in many places has been proved to be made up of a series of step faults, of which the united throw is always great and comparable in size to that of the Apedale Fault. It depresses the measures to the west, or in the opposite direction to the Apedale Fault; thus enclosing the anticline in the form of a wedge between the two.

As the western faults terminate the coalfield in this direction it is of importance to give all the information obtainable. Commencing at the Leycett workings north of the Hollywood Fault. Up to the present time no fault, with a northerly trend, of any

magnitude has been detected in driving out westward in the Bullhurst Seam. Further north in the Hayesdelph workings of the Apedale Company a Fault of 150 yards down west, sometimes known as the Bullhurst Fault, has been proved in the Four Feet Seam, and has been passed through at intervals in the Bullhurst Coal, as far north as 500 yards south-west of Miles Green. South of the Hayesdelph workings the fault is said to curve slightly to the west. It either does so, or else rapidly diminishes its throw, and becomes the minor fault represented on the map to the east of Hayes Wood. In sinking the Minnie Shafts, to the north of Wood Farm, the upper portion of the shafts were found to be in intensely faulted ground. The Red Shagg Ironstone was considered to have been passed through at a depth of 142 yards; and the Four Feet Seam at 329 yards depth. From this it is estimated that the faulty ground accounts for the absence of about 250 yards of strata. On analysing the ironstone, however, it was found to contain a large amount of lime, and to be poor in iron. This does not necessarily mean that the seam had been wrongly identified, for in this western area the Black Band ironstones have a tendency to assume the nature of limestones. The section, however, of the measures above and below the ironstone rather agrees with the sequence about the horizon of the Brown Mine. If so, the fault has a smaller throw than the above estimate, and would range between 150 and 170 yards. As previously stated (p. 103), there is good reason to believe that the red rock seen in the railway cutting to the east of Hayes Wood lies on the horizon of the Great Row Coal or a little below, an identification confirmed by a heading driven eastward from the surface at the north end of Hayes Wood. Now, red marls of the Etruria Marl type crop out in the western banks of the Hayes Wood Valley, and are overlain by grey flags a little north of Hayes Farm. At the south end of the wood an old level was driven close on the junction of the flags and marls, and an inferior ironstone, crammed with Entomostraca and containing a few specimens of *Anthracomya Phillipsi*, can be picked up on the spoil heaps. The grey flags probably belong to the Newcastle Group; but the close resemblance of the ironstone to that of the Rose Vale Brickpits (p. 130) 300 yards above the Red Shagg, or about 400 feet below the base of the Newcastle Group should be taken into account. If these ironstones are identical the throw would be between 250 and 300 yards.

There is no doubt that whatever may be the magnitude of the throw the stream valley through Hayes Wood runs along a fault. The valley continues as far as the easterly termination of Craddocks Moss, where it turns abruptly to the east for a few yards, and then resumes its former course down The Glading towards the Manor House. The abrupt turn eastwards marks the surface position of the Hollywood Fault, which thus appears to throw the Boundary Fault eastward, and would therefore be of a later date.

Mining operations have not been carried on to the west of The Glading, but on the eastern side an overthrust fault has been met with in the Seven Feet Bambury and Bullhurst coals from the Madeley Leycett Collieries. This suggests the probability, that in places at any rate, the western disturbance may in part be composed of an overthrust. In the small stream (Checkley Brook) issuing from the north end of the fish pond at the Manor House, some highly disturbed red sandstones of the Keele type are situated on the southern continuation of the line of disturbance. Further south the country is drift-covered, but at Bar Hill undoubted indications of faulting occur along the same line, and are continued as far south as Mucklestone.

In the area north of Miles Green the line of the western boundary disturbances is continued as a large fault running north-north-east from the Boyles Hall Pit to the junction of the roads 400 yards north-west of Audley Station. South of the Boyles Pit it is stated to trend in a more southerly direction. Mining operations show it to be a compound fracture, consisting of a number of step-faults progressively letting down the measures on the north-west. It has not been proved at the Audley Colliery whether this fault is terminated by the one which meets it at right angles from the Diglake shafts, but it seems on the whole probable that it continues farther to the north-east; for a fault in the same north-easterly direction was encountered at the Jamage Colliery, a short distance west of the railway near the Rookery Pits. Its position, at a depth of 60 yards, is somewhat east of the line of fault from the Boyles Hall Pits in the Ten Feet Coal at a depth of 90 yards.

Another north-westerly fault is proved in the Birchenwood Coal at a depth of 141 yards under Boyles Hall, while the ground between this and the main fracture is said to be intensely faulted. The measures have not been proved on the north-west side of the faults; but a very short distance beyond the more northerly of these two dislocations the red Etruria Marls crop out at the surface. The fault in the Ten Feet Coal is at a depth of 90 yards, and the hade will bring it to the surface about 300 yards from where the red marls are seen in the clay pit. This allows for the displacement within that distance of some 600 to 700 yards of strata up to the base of the marls, together with whatever thickness of marl may lie below the horizon seen in the marl pit. There is no doubt that the red marls belong to the upper part of the Etruria Marls (p. 132). Their thickness, however, is not known, and may be anything between 800 and 1,000 feet. An unconformity is out of the question (p. 53). There must, therefore, be a fault here of over 800 yards westerly downthrow, though the marl pit shows no indications of its near proximity—a not infrequent phenomenon near large faults. South of this area there are indications of a faulted overfold, and this may partly account

for the magnitude of the displacement. It may also be mentioned that at the Diglake Pits the western limb of the anticline bulges inwards at its foot, the Bullhurst Coal forming a sigmoid curve, and being passed through twice in one shaft.

NORTHERN PORTION BY C. B. WEDD.

Folds.—The course of the anticline, and the segments into which the several dislocations divide it, will be traced first. These segments often overlap. As followed from the south, by Bound Hill, the anticline is found to be interrupted by a curving fault, and to be displaced eastward, with a slight overlap, at the Diglake Pits, Audley.

Hence it continues north-north-east in Bignall Hill and Old Hill to the Jamage Colliery; north of which it bends abruptly westward for some distance before disappearing in that direction, the strata in the angle taking on a synclinal form.

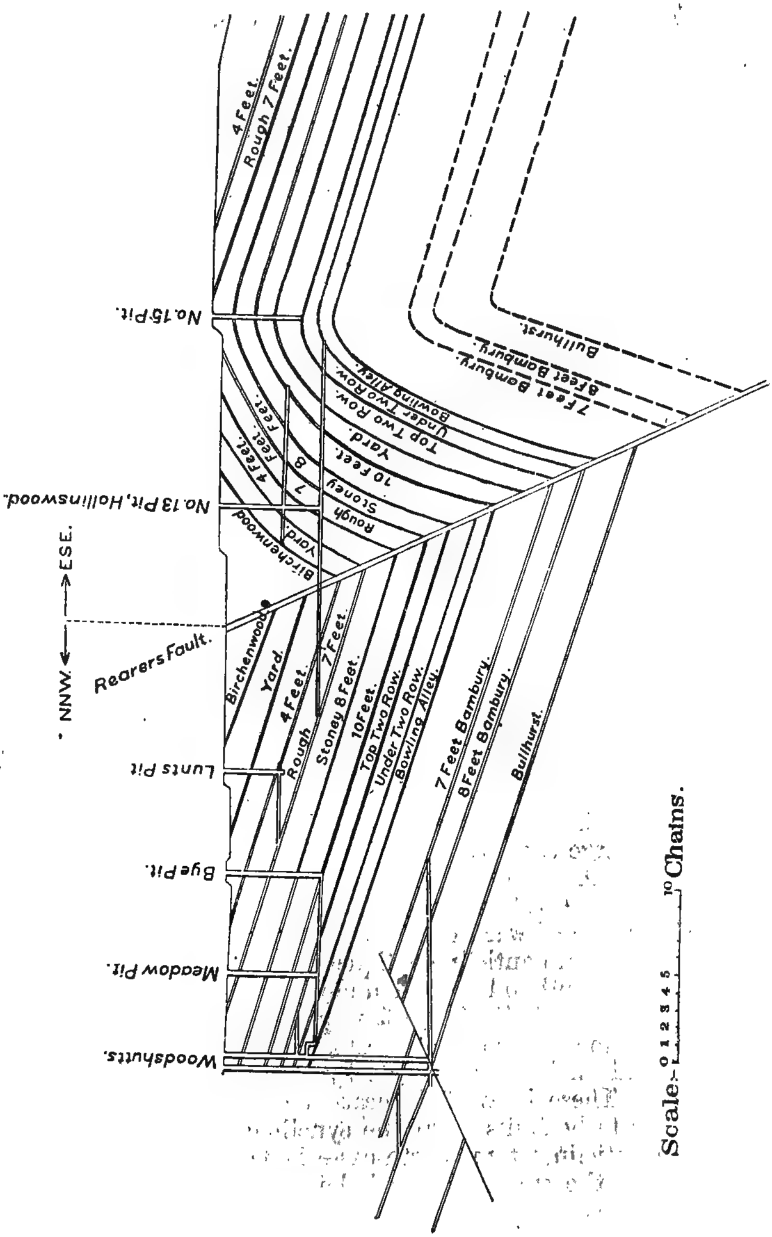
This westerly bend is evidently correlated structurally with a complication of the folding immediately to the north. What must be regarded as the northerly continuation of the main anticline, though of diminished size, is again displaced eastward, a fault intervening. A narrow faulted syncline on the west separates this saddle from a broad anticlinal dome of greater elevation, traversed by faults, and bounded on the south and west by a curving fault. The section on page 183 illustrates the folding. The western dome lies immediately north of and opposite to the westerly bend of the anticline at Jamage, and is separated from it by a fault valley. This western dome, though recognisable at Bunker's Hill, does not appear to extend much further northward. The eastern saddle runs between Talke and Hollinswood, where it is again traversed by faults, and undergoes an easterly displacement with considerable overlap of its two segments. Beyond here it again increases in elevation, the western saddle having died out, or become quite insignificant. Fig. 13 on page 179 shews the structure of this part of the district.

The structure of the ground west of the main anticline around Butt Lane is greatly complicated by faulting. The general dip of the strata in the southern part of it at Woodshutts Colliery is southerly, becoming westerly and then west-north-westerly at Red Bull. It is imposible to say whether the western saddle of the Talk o' th' Hill and Bunker's Hill collieries still continues here in diminished amount.

In speaking of the dislocation and progressive displacement of the main anticline in connexion with faulting, it must not be assumed that the faults cut and displace the fold in the same sense in which they displace an outcrop. It is not that an originally continuous anticlinal fold is severed and thrown out of position by subsequent faulting; the general line of

folding is certainly displaced in connexion with faulting; but it is probable that the overlapping segments of the fold, though

FIG. 13.
DIAGRAMMATIC SECTION ACROSS THE ANTICLINE AT HOLLINSWOOD NEAR TALKE, BY MR. J. MACGOWAN, JUN.



all belonging to the same line of folding, are in most cases of the nature of distinct segments which die down at the points where the faults separate them.

A certain amount of evidence exists for estimating the extent of the relative elevation of the strata in the anticline. From the known position of seams in the Diglake and Boyles Hall level-courses, and the thickness of beds in the shafts, it can be calculated that the Eight Feet Bambury Coal, between levels from these pits, rises some 410 feet in the fold without reaching either the summit of the saddle or the bottom of the trough on the west. Hence the altitude of the fold in the Eight Feet Bambury Coal under Bound Hill is more than 410 feet, perhaps considerably more. Some distance northwards it decreases. Similar evidence shews that at the Talk o' th' Hill Colliery, in the more easterly of the two anticlines, which continues the line of the main fold, the total amount of vertical displacement is only about 370 feet in the Seven Feet Bambury Coal, and apparently considerably less in higher strata. On the other hand the crest of the more westerly dome at the same colliery shows an elevation of more than 800 feet above the lowest point of the trough. Further north, under Clough Hall, the main fold, representing the eastern saddle of Talk o' th' Hill, has again increased to an altitude probably of 800 to 1,000 feet in the lower coals, but somewhat less in higher measures, above the corresponding beds in the low ground on the west.

The "rearers" of the west flank of the anticline in Bound Hill have a dip of 75 degrees west in the Eight Feet Bambury level, while in the Diglake Shafts they are slightly inverted at the foot of the saddle. In Old Hill the eastward dip amounts to as much as 70 degrees before flattening out suddenly; while the westward inclination probably does not much exceed 40 degrees and diminishes gradually. Again in the Hollinswood workings the westerly dip becomes nearly vertical; while the easterly slope in the eastern limb of the anticline remains at 18 degrees for some distance. In all three cases the higher dip is on the side of a large fault bounding the anticline.

Faults.—A main line of fault known in the district to the south as the Apedale Fault (p. 165), with great easterly downthrow, runs northward on the east side of the anticlinal system, crosses the main anticline obliquely, and continues along its west side to Red Bull and beyond under the names of the Millstone and Eighty Yards Faults. A fault parallel in its northern part to this fault line comes in on the east, crosses the anticline, and runs northward on its western side by Hollinswood and Harecastle Station. These lines of dislocation receive on the east many north-westerly faults from the synclinal region. On the west of the anticlinal tract north-easterly faults (pp. 175 and 187) terminate the surface-area of the productive measures.

It will be seen that the main lines of fracture of this system, as they converge northwards, exhibit ramification in two opposite directions. Besides diverging southwards, and throwing off branches in this direction, they also have a marked tendency to split up northwards towards their common apex. Thus they

produce an intricate plexus of intense faulting in the district of Talke and Harecastle. Another striking characteristic is the way in which the faults from the south, here always with easterly downthrow, twist westward in crossing the anticline.

In the workings of the Jamage Colliery a northerly fault of large displacement, with easterly downthrow, is generally known as the Millstone Fault, on the assumption of its continuity with the fault of that name at the Talk o' th' Hill Colliery. It throws off a south-westerly offshoot with a south-easterly downthrow of 15 yards in the Eight Feet Bambury Coal. The Millstone Fault of the Jamage Colliery seems to be the main fracture of the Apedale Fault. It runs along the valley separating the area of anticlinal uplift on the west from the synclinal depression on the east. The amount of downthrow is not known, as the coal-seams have not been identified on the east side. That it is great is evident, as it brings beds of a high horizon in the productive measures on the east against a low horizon in the same series on the west. The displacement must, however, decrease rather rapidly northward, for the north-easterly strike of the measures on the east brings successively lower horizons northward against approximately the same horizon in the lower part of the series on the west.

Near the Jamage Colliery this fault, or perhaps only a branch of it, is proved to be bending somewhat westward, rather too far in fact, to admit of its easily joining the Millstone Fault of the Talk o' th' Hill Colliery, which in all probability continues the main fracture.

A fault, not shown on the map (1st Ed.), running slightly north of west, with northerly downthrow, has been proved north of the Jamage Colliery under the northern flank of Parrots Drumble at a depth of 300 yards in the Eight Feet Bambury Coal. From it two small faults, also not on the map, each with easterly downthrow, run east of south, cutting the westward bend of the southern anticline. The more westerly of these passes under the western flank of Old Hill, in the Eight Feet Bambury Seam, and has a downthrow of 20 yards. The eastern one has the same amount of downthrow in the north, but dies out southward. It was traced in the Eight Feet Bambury Coal along the anticlinal axis under the crest of Old Hill.

Another fault in the same direction, but with westerly downthrow, has been met with in the Rookery Pits of the Jamage Colliery.

The Millstone, or 125 Yards Fault, of the Talk o' th' Hill Colliery runs slightly east of north, and almost coincides with the axis of the syncline in the lower coals. It has a downthrow to the east diminishing northward from 70 to 56 yards. In the Seven Feet Bambury and Bottom Two Row coals the hade is gentler in the north than in the south. Along the crest of the eastern anticline at the Talk o' th' Hill Colliery, a fault, with a westerly downthrow of 20 yards, has been proved in the Seven Feet Bambury Coal at a depth of 320 yards. An east and west

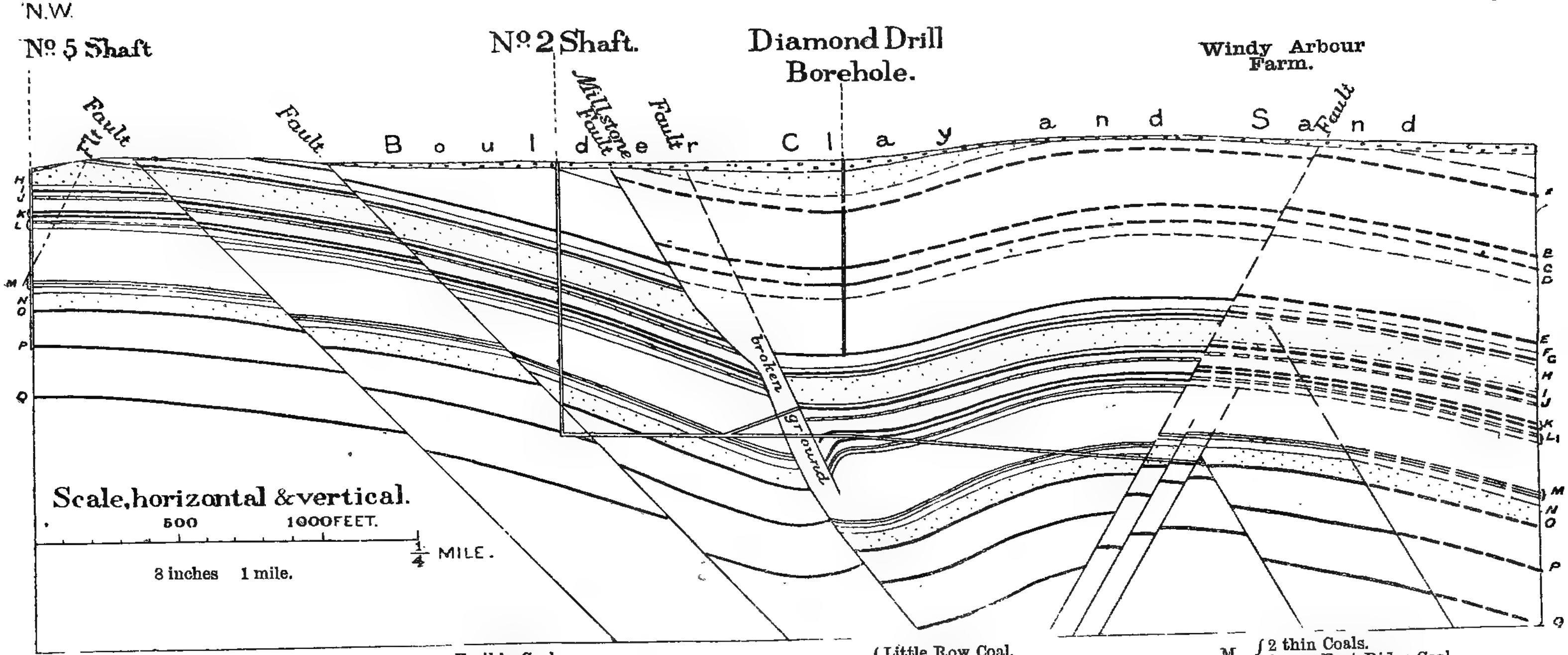
fault with a southerly downthrow of 20 yards has been proved in the same seam 300 yards south of Windy Arbour Farm. A fault traced in the Eight Feet Bambury Coal trends at first north-west, and curving nearly to the north appears to be a branch of the Millstone Fault. It has an easterly downthrow, increasing northward from 20 to 40 yards. A fault with an easterly downthrow of 15 yards, and north-north-east direction, has been traced in the lower coals from 200 yards west of the shafts of the Talk o' th' Hill Colliery, through the workings of the Bunker's Hill Colliery as far as Butt Lane. West of Hollins the downthrow has increased to 40 yards. The hade becomes less northward. This fault cuts, and slightly displaces, another curving fault which crosses the syncline about 450 yards south of the Talk o' th' Hill Colliery in the Eight Feet Bambury Coal. Its course is at first west-north-west, bending round to north under the road from Talke to Dunkirk, and hereabouts throwing out several branch-faults, which diverge and converge again so as to enclose small, boat-shaped areas. All but the most westerly one of these faults have an easterly downthrow. The throw of the main curving fault is 60 yards down north-east in its south-eastern part, and again near New Springs, but it increases temporarily to 120 yards, where the fault crosses the end of the local western dome (see section, p. 183). The fracture, with its temporary increase and curving form, is evidently one of local adjustment, due to the uplift. Its proved dislocation by a transverse fault parallel to the axis of the uplift affords a good illustration of the probable interrelation and order of folding and faulting, thus:—The incipient uplift produces first a marginal rupture by adjustment to its surroundings; then, as it increases in elevation, a transverse fault making its appearance gives internal adjustment between the parts of the dome, and displaces the marginal fault.

The majority of the small faults affecting the system of folding at the Talk o' th' Hill Colliery have, according to Mr. Henshaw, a downthrow in the direction of dip, that is, they are successive steps in the progressive elevation or depression of the strata.

The 80 Yards Fault.—A fault, which seems to belong to the same belt of fracture as the Millstone Fault, runs south-south-west from Lawton, where it may start from the Red Rock Fault, to Red Bull. Thence it bends east of south, running nearly parallel to and not far from the Millstone Fault. It is known locally as the 80 Yards Fault, from its having this amount of easterly downthrow. It splits into two branches at the Woodshutts Colliery, one of these apparently joining an eastern branch (p. 184) of the Millstone Fault near Hollinswood, the other reaching, or nearly reaching, the fracture known as the Rearers Fault (p. 184) near Clough Hall.

To return to the south of this district, east of the Apedale Fault, in the neighbourhood of Chesterton, several north-westerly

Fig. 14.—Section through the Ground of the Talk o' th' Hill Colliery Co. (based on Colliery sections and the "New Ten Feet Crut"), by C. B. Wedd.



A. Bee (?) Coal.
B. Birchenwood (?) Coal.
C. Mossfield (?) Coal.
D. thin Coal.
E. Rough Seven Feet Coal.

F. thin Coal.
G. Stony Eight Feet Coal.
H. Ten Feet Rock.
I. Ten Feet Coal.
J. Two Row Rock.

K. { Little Row Coal. Two Row Coal.
L. { Muck Coal. thin Coal. Rowling Alley (?) Coal.
Q. Bullhurst Coal.

M. { 2 thin Coals. Seven Feet Rider Coal.
N. Bambury Rock.
O. Seven Feet Bambury Coal.
P. Eight Feet Bambury Coal.

faults, nearly all with north-easterly downthrow, either die out or run into the Apedale system of faulting.

The High Carr or Newcastle Fault. The High Carr Fault, a continuation of the Newcastle Fault (p. 164), trending north-west, has a downthrow of 110 yards to the north-east, as proved in the Red Mine south of High Carr. North of the same locality the displacement proved in the Great Row is only 90 yards. The disappearance of the grit-ridge at the base of the Etruria Marls at High Carr, and of another grit-ridge further north, indicates the surface position of the fault. Its further course is uncertain.

The Bradwell Wood Fault.—North of the High Carr Fault, in the same north-westerly direction, a fault was met with in a footrill in the Burnwood Ironstone, close to the crossing of the roads to Newcastle and Audley. It has a downthrow to the south-west, as have all the north-westerly faults north of the High Carr Fault as far as the Bath Pit of the Birchenwood Colliery, where a fault in the same direction throws down north-east. All these probably run into the southerly continuation of the fault now to be described.

The Rearers Fault.—This fault passes in a north-north-east direction between the dislocated segments of the anticline at Hollinswood, and continues in the same direction on the west side of the anticline (figure 13, p. 179). At the Hollinswood Colliery the fault has a throw of 95 yards down east, and a hade of 64 degrees, according to Mr. MacGowan; but the hade seems to diminish northwards. The fault appears to pass southward along the depression east of Windy Arbour, as far as the parting of the roads to Newcastle and Red Street. But whether it dies out here or unites with the High Carr Fault, there is no evidence to show; though the two faults in all probability belong to the same belt of fracture.

*The Millstone, or 126 Yards Fault.**—This is a fault having a north-westerly direction, which leaves the Rearers Fault near the north end of Hollinswood, and skirts the high ground of Talke along its north-east flank, truncating the western segment of the main anticline. It joins the Millstone or 125 Yards Fault* of the Talk o' th' Hill Colliery close to Hollins, thus connecting the Newcastle and Apedale fault-systems. It has a proved throw of only 26 yards down north-east; but the ground west of it has not been worked, and the fault proved may be only one of a series of steps.

A much-faulted tract lies between the Rearers and the Eighty Yards faults. It is intersected by numerous branch-faults running north-west and south-east from the Rearers and Eighty-Yards Fault respectively. These branch-faults often subdivide into smaller ramifications, the two series frequently overlapping. They all have a north-easterly downthrow.

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* The two Millstone Faults are said to have been named from an old mill at Butt Lane.

The southern part of the Eighty-Yards Fault splits into two branches at the Woodshutts Colliery. One of these apparently joins the eastern limb of the Millstone Fault near Hollinswood the other reaches, or nearly reaches, the Rearers Fault near Clough Hall. Between these two branches a fault runs north-west from the Rearers Fault at the Hollinswood Colliery, diminishing from a displacement of 60 yards and dying out before reaching the Eighty-Yards Fault.

A branch leaves the last-named fault at the Butt Lane School, and runs to the Woodshutts Colliery, with a maximum displacement of about 15 yards. Another diverges from the same main fault at the canal at Red Bull, running close under the west side of the railway before splitting into two branches, of which the more northerly has a throw of 15 yards.

An off-shoot leaves the Rearers Fault at the north end of Clough Hall Park, and has a displacement of 40 yards. At the canal, near the Gas-works, it divides into three with downthrows of 40, 40, and 17 yards in order from west to east. Another branch leaves the Rearers Fault west of Harecastle Station, runs north-north-west with a downthrow of 53 yards in the usual north-easterly direction, and then swerves round westward towards Red Bull. Another fault, which probably also splits off from the Rearers Fault, bends almost due north, with easterly downthrow, and runs west of the railway (Macclesfield Branch).

A fault, running roughly eastward and soon bifurcating, starts from the Eighty-Yards Fault north of Red Bull and has a northerly downthrow.

As the Red Rock Fault approaches the anticlinal system and the apex of the radial faulting, the intensity of the faulting evidently increases. At the Talk o' th' Hill Colliery, between the Red Rock Fault and the local western anticline, a narrow belt of ground is so completely shattered that the coals in it cannot be worked, and the same state of things probably exists elsewhere in this part of the district.

To appreciate the principles underlying the radial system of faulting, and its relation to folding as affecting this northern anticlinal district, it is necessary to bear in mind: firstly that we are here dealing with the tapering northern end of a tract stratigraphically of great relative elevation, limited by the Apedale and Newcastle faults with eastward downthrow on the east, and by the Western Boundary and Red Rock Faults with westerly downthrow on the west; secondly, that the relative elevation of this tract is diminishing northwards, as the eastern faults decrease in that direction; and thirdly, that the eastern boundary of the tract necessarily crosses the anticlinal saddle obliquely in the north, before reaching the faults of the western boundary.

The invariable eastward or north-eastward downthrow of all the faults within the uplifted tract from Wood Lane northward, which cross the anticline and displace its northern continuation

to the east, clearly owes its origin to the northward decrease of uplift in the elevated tract, shown by the dwindling of the eastern boundary faults in that direction, the sum of the eastward downthrows as they severally cross the anticlinal axis bearing a relation to the amount of northward diminution of the Newcastle and Apedale faults, and bringing about a northward depression of the elevated tract. This tract, uplifted bodily in the south between large single faults, is thus let down again in successive slices in the north towards the general surface-level of the rocks on the east.

As the Red Rock Fault, though not continuous with the Western Boundary Fault, is certainly a part of the same belt of fracture, so the Millstone Fault of Jamage, the fault of the same name at Talk o' th' Hill, and the Eighty-Yards Fault of Butt Lane, clearly represent the line of fracture of the Apedale Fault, though, perhaps, not all one simple fault. Similarly it is highly probable that the Rearers Fault, most likely not itself a continuation of the Newcastle Fault, is a prolongation of the same belt of dislocation.

Where the Apedale and Newcastle fault-systems, represented by the Eighty-Yards and Rearers faults, approach each other in the north, they are connected by a series of interlacing off-shoots from each, which mark successive steps in the same direction. Hence arises the north-easterly downthrow of all the branch-faults near Butt Lane. But faults which join the Rearers Fault on the east side, outside the area of elevation, have often a south-westerly downthrow, *e.g.*, those between High Carr and Bath Pool.

Again the same considerations of easterly or north-easterly downthrow in the northern part of the uplifted tract account for the direction of downthrow of the curving fault which bounds the western dome (Fig. 14, p. 183), at Talk o' th' Hill. This fault, as limiting that dome, might otherwise be expected to have a throw down south-west.

Incidentally these considerations explain why the Rearers Fault, forming the western boundary of the anticline at Clough Hall, has an easterly downthrow; while the anticline at Bound Hill, Audley, is limited on the west by a westward downthrow. In the latter case the anticline is within the uplifted area and on the west side of it, while in the former it lies without that tract and east of it.

The district affords further examples of the inter-relation of faulting and folding. The anticline from Wood Lane to Jamage distinctly pitches down northward, as shown by the presence of successively higher strata on its crest in that direction from the Bullhurst up to the Ten Feet Coal. From Mow Cop to Talke it pitches down southward.

The anticlinal fold is therefore depressed in the middle of this district. The Talk o' th' Hill segment of the fold shows its lowest depression, for here the Bee Coal is near the surface on the

crest. Moreover, in this segment the fold has a comparatively small altitude, and is supplemented by a subsidiary anticline on the west, which is actually larger (figure 14, p. 183). It is in this depression of the anticlinal ridge that the converging Apedale and Newcastle fault-systems cross the fold, and the most depressed segment of the saddle, where it is a comparatively small anticline, is isolated between these two fault-systems.

It may further be suggested that in this district the closeness of the radial faulting, which crosses the folds obliquely at small intervals, with north-easterly downthrow, performs the function of adjustment which the transverse faults fulfil in the Biddulph district, outside the system of radial faulting. Hence the complete or almost complete absence of transverse or east-and-west faults in this district.

The Red Rock Fault.—This line of powerful fracture, which trends in a nearly straight line north-eastwards from west of Audley, bounds the coal-field on the west. When followed northward it is found for some distance to throw down on the north-west successively higher strata of the Trias against successively lower beds of the Coal-measures; from the Newcastle Group at Audley to a low horizon in the Grey Series near Linley Wood. North of Audley the position of this fault is closely defined by the northern end of the ridge of the Newcastle sandstone, and the hill of Bunter sandstone, on which the old workhouse stands, south of Cross Farm. South of Swallowmoor Wood the fault does not run along the narrow drainage valley, but passes through the flank of the high ground on the south-east, for Bunter sandstone forms both banks of the valley. Coal has been worked beneath this valley, the Red Rock Fault being proved immediately to the west, at a depth of 120 yards. A little further north, the surface-position of the fault must run along the valley on the south-east of Linley Wood. The hill on which Linley Wood is situated appears to consist of Keuper sandstone (p. 149) Under its south-eastern flank coal has been worked for a short distance nearly as far as Linley Wood Hall, before the Red Rock Fault was met with. The fault is again stated to have been touched in a stone-drift from the Lawton Pits. Further north, Coal-measures are seen at the surface in a stream by the side of the road to Congleton, in a position immediately east of the line along which the fault may be expected to reach the surface, while Trias is found on the west in Lawton Park. The hade of the fault appears to be rather steep.

Green mentions Ford Sprink south of Kent Green, "where the railway crosses the brook," as a locality where the fault was visible in a section.* No section exhibiting the fault is now to be seen, but there is ample evidence of its occurrence. Bunter

**Mem. Geol. Survey.* Geology of Country round Stockport, Macclesfield, Congleton, and Leek, p. 8.

sandstone is exposed in the brook immediately west of the railway bridge, and again in the cutting of an old mineral tramway, 50 yards south-east of the railway and 100 yards north-east of the brook. It would seem that the exact position of the fault is a short distance east of the bridge. Northward from here the surface-position of the fault is fairly well defined by exposures of Triassic and Carboniferous rocks on either side, and by springs in Quarry Wood. The Red Rock Fault is still visible in the Grotto Wood section (pp. 146 and 149), about 100 yards east of a large disused quarry, in a cutting in the lane which runs north-west along the south-west side of that wood, as recorded by Green. Soft red loamy sandstone with a few pebbles, dipping west, is thrown against crumpled grey shales. On the west side of the Astbury Limestone Quarry, the Limestone was said to abut against Trias.* Further north the fault is again met with in the Dane.† Thus there are ample data to show that at any rate in the southern part of its course the Red Rock Fault is an actual fracture, though the amount of displacement is quite unknown. Owing to the strong unconformity of the Trias, a comparison of the Triassic and Carboniferous horizons on either side of the fault affords no clue; neither is the thickness of Triassic strata near the fault any criterion of the displacement, because the Trias was probably to some extent banked against a strong slope of Carboniferous rocks before the fault existed, or before the latest movements took place along an old fault-line. It is not improbable that the fault was in part pre-triassic, so that there may be a greater displacement in the Carboniferous Rocks than in the Trias.

Apart from a few small faults running from the Red Rock Fault on the west, nothing is known of the system of faulting in the Triassic plain on that side of it.

Faults and Folds in the Trias.

It is not intended to enter into these in any detail. In the Fulford area Mr. Pocock recognised the existence of slight rolls in the Keuper formation. These become more pronounced in the Forsbrook, Blythe Bridge and Caverswall areas. The Keuper marls and sandstones of the southern part of this district are seen to be thrown into a series of gentle folds with their axes running in a general north-westerly direction and apparently rather more northerly in the west. It is probable that the eastern anticline of the Pottery Coalfield, traced southward to Werrington, though it there diminishes in amount, does not die out, but continues in the Trias; for the red marls of Blythe Bridge and Caverswall show an arrangement of slight folds corresponding in trend with those of the Carboniferous rocks. Thus a gentle anticline, the crest of which is clearly visible

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* Op. Cit., p. 9. † Lo. Cit.

in the cutting of a mineral railway to the Foxfield Colliery south-east of Caverswall, runs in a south-easterly direction by Forsbrook; and is probably the feeble representative of the eastern uplift of the coalfield, continued after Triassic times. West of it the Trias has a general synclinal arrangement, probably consisting of several still smaller folds. The prevailing direction of the faulting is north-westerly or northerly, but east-and-west faults also occur.

A complicated system of step-faults is exposed in the cutting at Meir Station. The faults in the Trias to the north have already been mentioned (p. 156).

In the neighbourhood of Stableford and Maer the various sub-divisions of the Trias are evidently much faulted. The actual fractures are not seen, but the unusually high inclinations of the strata at Maer, and the broken character of the ground are sufficient evidence of the presence of the faults shown on the map. The unusually straight valley between Whitmore Station and Madeley Road is strongly suggestive of a fault, and this is partially indicated by the shift in the outcrop of the base of the Bunter between Snapehall and Madeley Park Farm, on opposite sides of the valley.

As the broad expanse of Triassic rocks is followed westward from the eastern and disturbed areas of the Carboniferous rocks, so also do the disturbances lessen in amount, and the Trias reposes on the higher Coal-measures at about the same angle. On approaching the southerly continuation of the western anticline disturbances again make their appearance. This is notably the case around Ashley, Oakley and Mucklestone. It is further noticeable that as the faults in the Carboniferous rocks swing from a north-north-west direction to a north-north-east direction, in going from east to west, so do the faults in the Trias, suggesting a close tectonic relationship between the two discordant systems.

The faulting in the south-western and western areas is closely associated with the stratigraphy, the fractures being rarely visible and generally inferred from the want of regularity in the succession. They are therefore mentioned in the account of the Trias.

CHAPTER X.

THE BUTTERTON AND SWYNNERTON DYKE.

BY W. GIBSON.

Historical.—It has long been known that the southern margin of the North Staffordshire Coalfield presents the unusual phenomenon, in the Midlands, of a narrow dyke of igneous rock penetrating the later Carboniferous and Triassic deposits. The small mass near Yarnfield is indicated on the 1-inch Survey map (72 S.W.), but Charles Darwin seems to have been the first to notice its existence near the lodge gates of Butterton Park, and to have mentioned the fact to Sir Roderick Murchison. It was also known to Dr. Garner.* The petrology was first described by Allport† and subsequently by Dr. Teall.‡

The fullest account has been furnished by Mr. Kirkby, who conclusively proved that the date of its intrusion must be post-Triassic. Sir Thomas Wardle also noted it at Norton Bridge, the southernmost point at which it is yet known. Its resemblance to the intrusive rocks of Titterstone Clee and Rowley Regis has been commented on by Professor Watts, and the similarity of the coarser varieties of these igneous rocks to the Tertiary dolerite dykes of the north of Ireland, Scotland and the Isle of Man pointed out

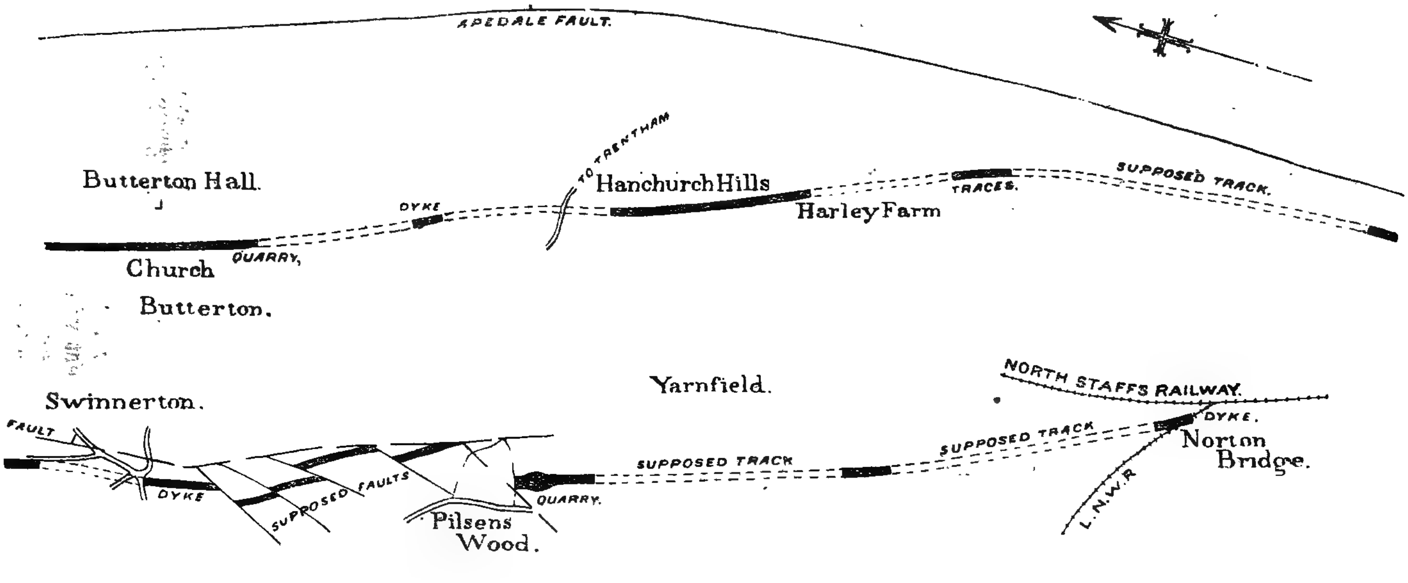
Stratigraphical.—The dyke appears at the surface only at widely separated intervals along a low ridge regardless whether this consists of rocks of Carboniferous or Triassic age, and becoming lost to sight when the ridge dies away. It would also appear to bear some relation to the Apedale Fault, the chief disturbance in the district, for the dyke is always roughly parallel with it from Butterton to a little north of Swynnerton, and swings to the east or west as the fault changes its direction. It will also be seen that at Swynnerton there are reasons to believe that it is dislocated by the branches of this fault.

The most northerly point at which the dyke can be seen is in the road leading to Butterton Village, at a spot 50 yards south-south-west of the lodge gates. Vegetation and soil obscures the outcrop, but igneous rock juts out on the north banks, and by careful observation on the south side of the road its total width of eight feet can be satisfactorily made out. The walls are formed by the red sandstone of the Keele Group, and for a distance of two feet from the dyke, on the north side of the road, it is changed into a

* Natural History of the County of Stafford. *London*, 1844.
† *Quart. Journ. Geol. Soc.*, vol. xxx., p. 214.
‡ British Petrography, p. 529.

FIG. 15.

PLAN OF THE BUTTERTON AND SWYNNERTON DYKE. (AFTER J. KIRKBY, *N. Staffs. Field Club.* VOL. xxviii.. 1894.)
One inch = about one mile.



yellow black-spotted rock, very soft and slightly more micaceous than the normal unaltered rock. On the south side of the road the alteration is less obvious, though for a few feet away from the dyke the red sandstone has an olive green colour along the joints, a weathering characteristic of the Keele sandstone in proximity to the dyke in the Butterton Quarry to the south. Except near its edges the material of the dyke is undecomposed close up to the surface.

The igneous rock is said to have been obtained in a drain to the north near the Lymes Farm. No indications of its presence are now seen, and no traces could be found anywhere on the Keele Park Estate; neither is it known within the present limits of the coalfield, although there are numerous workings extending close up to the Apedale Fault and across the northerly path the dyke would take.

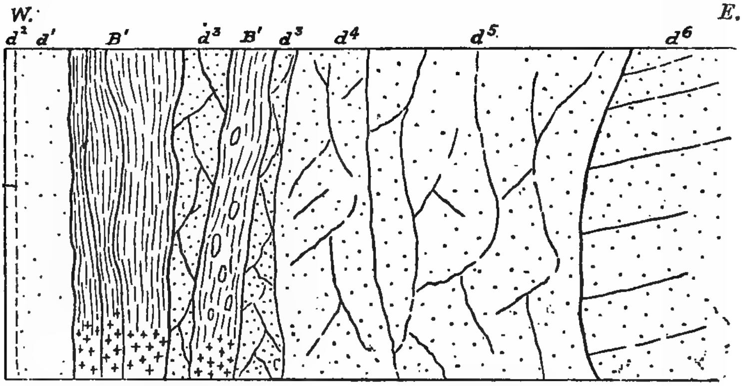
A low ridge extends in a south-south-easterly direction from the section near the lodge gates and this, no doubt, marks the course of the dyke, for at its southern termination a quarry has been opened 300 yards to the south of Butterton Church, which shows the dyke intruded into the red Keele sandstone.

There can here be no doubt about the intrusive nature of the rock; and, as the Keele sandstones are now certainly known to belong to the highest part of the Coal-measures visible in North Staffordshire, the date of the intrusion must, at any rate, be post-carboniferous.

The following sketch illustrates the relation of the igneous material to the encasing red sandstone (fig. 16).

FIG. 16

IGNEOUS DYKE IN THE KEELE SERIES, BUTTERTON PARK By W GIBSON



d2. Unaltered sandstone.
d1. Altered do. 3 feet wide.
B1. Dolerite dyke 8 feet wide.
d3. Altered Grit 4 feet to 3 feet wide.
d4. Soft white sandstone 10 feet wide.
d5. Olive coloured sandstone.
d6. Red sandstone.

The dyke is nearly vertical, and strikes north twenty degrees west. It is fifteen feet wide at the top, but tapers to twelve feet at the bottom of the excavation. A wedge of highly altered grit (No. 3618, p. 196), four feet thick at the top and two feet six inches

wide in the floor of the quarry divides the dyke into two portions. On the north side of the quarry, the igneous material is of a soft crumbling nature, exhibiting a platy structure parallel to the dyke walls, and containing, scattered through it, rounded masses of dolerite. The floor of the quarry and the south side the dyke consists of solid dolerite. It is used for the garden paths of Butterton Hall, but it is too soft for good road-metal.

The contact alteration set up in the surrounding rock is mainly of a physical character. The metamorphism extends for over 27 feet on the east, but for not more than 5 feet on the west. For a distance between one and two feet from the eastern wall of the dyke, the Keele sandstone has been baked into a very hard grey grit, containing grains of opalescent quartz. East of this the red sandstone has been changed into a soft white rock, passing eastward into a yellow and olive green very soft sandstone, up to a curved slickensided surface, east of which the normal red colour prevails. The curved slickensided junction of the altered with the normal rock has all the appearance of a fault, and this is further emphasised by the jointed and broken strata to the west. The alteration of the walls on the west side is more intense in character, though it has not extended to so great a distance. It is particularly well illustrated by a band of breccia (No. 3613, p. 196), the included fragments of which have been hardened and baked.

For over a mile to the south-south-east, there is little surface evidence, but Mr. Kirkby found fragments of basalt and traces of the dyke in the fields near Hanchurch Farm. In the quarry in the orchard the Keele sandstone is much jointed and faulted, and is evidently on the same line of disturbance as the Butterton quarry.

A little south of Hanchurch Farm the Keele Group is uncomformably overlain by the conglomerates of the Bunter, which form the picturesque wooded ridge of the Hanchurch Hills. These are trenched by the road from Trentham to Hanchurch, and the dyke is exposed 200 yards to the east of the cottage on the edge of Swynnerton Old Park. The dyke here consists of two portions, but only one is now to be seen.

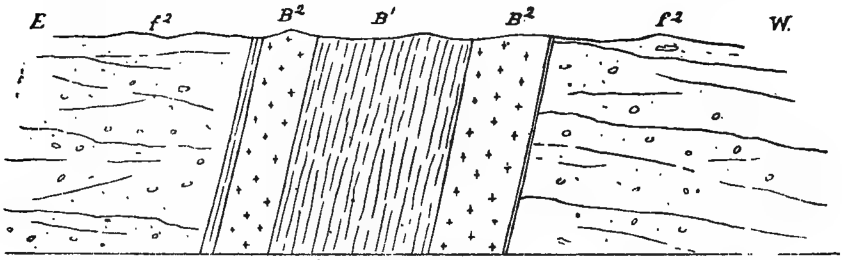
Two hundred yards to the north of the road the dyke is just visible in an old trench in the thick wood, but its relation to the Bunter is not ascertainable. This relationship is very clearly shewn in the following sketch (Fig. 17) of the section in a low bank twenty yards within the wood on the south side of the road cutting.

Its intrusive character is unquestionable. It is not possible to assert that it is situated on a line of disturbance, for though the inclination of 15 degrees observable in the conglomerates is unusually high for the district, yet it is by no means unlikely that the apparent inclination is really due to false-bedding.

The dyke is inclined at 79 degrees, and strikes nearly north and south. It consists of two masses of hard dolerite (Fig. 17), resembling that at Butterton, and separated by

FIG. 17.

IGNEOUS DYKE IN THE BUNTER SANDSTONE, HANCHURCH HILLS. BY W. GIBSON.



f2 Bunter conglomerate. B2 Olivine dolerite. B1 Decomposed rock.
f2 Bunter conglomerate.

a narrow band of the same crumbling substance seen in the top part of the Butterton quarry. The alteration of the contact rock is slight, consisting of a small amount of discolouration and partial hardening.

Traces of the dyke were found by Mr. Kirkby near Harley Farm, and about half a mile farther south; but from here to Swynnerton Hall there are no indications of its ever reaching the surface. Mr. Kirkby notes its occurrence beneath the lawn at the Hall, just beyond the southern margin of the map. The Apedale Fault (Fig. 15, p. 191) is evidently of considerable size near the fish ponds at the north end of Swynnerton Village and its line, if continued, would cross the eastern portion of the lawn at the Hall, and a short distance afterwards would cut the dyke. This would appear to account for the difference in its course and behaviour south of the Hall. Mr. Kirkby draws it as one continuous line from the Hall to the old clay pits north of Yarnfield. This is not strictly correct. A fine grained dolerite (No. 3621, p. 191), which has baked and hardened the surrounding sandstone (probably of Keuper age), is visible in a coppice near the old brickworks south of the Wellyard Plantation, and again 200 yards to the north. The dolerite evidently forms portion of a dyke which strikes north-north-west and south-south-east. In the Doles Coppice, 300 yards to the south-east of the brickworks, in the northern and south western ends, a dolerite dyke cuts Keuper Marls. Though the exposures are much overgrown the strike can be determined to be a little more to the west of north than in the brickworks. The dyke south of t e Hall is therefore either composite, or is dislocated by the Apedale Fault, and its branches. If the latter solution is correct and the dyke is of Tertiary age then some of the movement of the Apedale Fault must also post-date this period.

South of Swynnerton Park the ground has not been surveyed in any detail. The general direction of the dyke will be understood from the map (Fig. No. 15), and for further information the reader is referred to Mr. Kirkby's paper (*op. cit*). The igneous mass in the quarry south of Pilsens Wood is much larger in extent than anywhere to the north, and may indicate its closer proximity to the source from which the material of the dyke emanated. At Norton Bridge the igneous rock was observed by Sir Thomas Wardle in the foundations for some sheds, but it is no longer visible.

Petrological.

BY DR. J. S. FLETT.

3617 E.* *30 feet from east wall of dyke.* A reddish felspathic sandstone, fairly coarse grained, the average size being ·5 m.m. Quartz is common in rounded and subangular grains full of fluid cavities. Felspar is, perhaps, even more abundant, and is partly orthoclase and partly plagioclase, though it is often too much weathered to be determinable. Fine flakes of brownish laminated shale consisting of minute quartz grains with micaceous and argillaceous *débris* are so numerous as to form a considerable part of the mass. They are broken and splintery, not usually rounded. There are one or two pieces of muscovite, and biotite and black opaque patches, probably ferruginous. Between the other ingredients there lies a fine argillaceous and quartzose matrix, with a small amount of calcite.

3611. E. *27 feet from east wall of dyke.* A felspathic sandstone which is stained with limonite. Contains quartz, weathered felspar, fragments of shale and sheared quartzite, with a few large pieces of muscovite.

3612 E. *12 feet from east wall of dyke.* A speckled fine-grained sandstone which consists of quartz, felspar, small flakes of shale and fine quartzose and argillaceous *débris.* A few of the pebbles appear to belong to a sheared quartzite.

3615. E. *6 feet from east wall of dyke.* A pale greyish impure sandstone with quartz, weathered felspar, irregular bits of shale, fragments of sheared quartzite, a little muscovite and biotite, iron oxides, zircon. In this rock quartzite fragments are pretty common. There are some pebbles which look as if they were derived from the ground mass of old quartz porphyries or rhyolites. Most of the quartz is granitic.

3616 E. *3 feet from east wall of dyke.* Pale grey speckled sandstone consisting of quartz, abundant felspar, fragments of shale and little pebbles of sheared quartzite, with others which

* The numbers refer to the slides of the English collection of rocks in the Jermyn Street Museum.

look like fragments of quartz porphyry—a little biotite and muscovite and iron oxide.

3613. E. *3 feet from west wall of dyke.* A breccia or very impure grit, which consists of pebbles of quartz, felspar, fine shale and quartzite: an abundant matrix of quartzose and argillaceous *débris* stained with limonite. The shale fragments in this rock appear to be distinctly baked. They are very micaceous.

3619. E. *6 in. from west wall of dyke.* An impure greenish felspathic sandstone. The pebbles are mostly quartz, but fragments of a sheared quartzite are also common. There are a few felspars, and very few of a fine laminated shale. The matrix between these grains is rather abundant, and is very compact; it looks as if it were indurated, and is on a whole more of a crystalline mosaic than is usual in these rocks. In this fine crystalline quartzose mass a few minute crystals of fresh dark brown biotite can be found. It is probable that contact alteration has induced a partial recrystallisation of the matrix, but this biotite is a new contact product, and its development has been accompanied by the formation of incipient hornfels structure.

3618 E. (d^3 Fig. 16, p. 192). Finer grained, the particles averaging less than ·5 mm in diameter. They are again quartz, decomposed felspar, fragments of shale, quartzite (sheared); this rock is not only finer grained but also distinctly more quartzose than the previous slides. In a hand specimen it looks distinctly indurated, and under the microscope the matrix is often a fine crystalline mosaic, which resembles a hornfels. Minute idiomorphic six-sided scales of biotite have been developed in the groundmass, but as the rock is somewhat decomposed they have in many cases been altered into chlorite.

3614 E. *Centre of dyke, Butterton Quarry.* This is an olivine dolerite. The rock is very fresh, and contains large phenocrysts of olivine, some of them being about 2 mm. in length They are usually somewhat rounded, but are often sufficiently idiomorphic to show the typical lozenge-shaped rhombic sections. Some are ideally fresh, but many show thin films of serpentine forming on the surfaces and along the cracks. The enclosed small octahedra, many of which are black and opaque (magnetite), but others are green or brownish green, transparent, with a very high refractive index and isotropic, and these are probably spinel or chromite. Small rounded glass cavities are also present in the olivine. There is no porphyritic augite or felspar. The ground mass of the rock is a crystalline granular mixture of a purplish violet augite with lath-shaped plagioclase felspar. The felspars are scattered irregularly without definite orientation, and are idiomorphic, while the augite is moulded upon their surfaces, so that the

structure is subophitic. Dark grains of iron oxide are abundant, and small brownish stains of limonite. In the ground mass of the rock small patches, which are almost quite isotropic, often lie between the felspars, and they are probably the remains of a glassy base, with perhaps nepheline, as they often have a very weak double refraction, a distinct cleavage, and a lower refractive index than the felspar. There are a few long needles of apatite.

3620 E. *Dyke near Lodge Gates, Butterton Park.* This is a rock of a similar character to the preceding, with phenocrysts only of olivine and a groundmass of plagioclase and augite. Green octahedra of spinel or chrome spinel are also present. The groundmass is of a subophitic type. In this section there are patches, rudely circular in outline, of finer-grained material, which is principally felspar in radiate or featherlike aggregates and grains or skeleton growths of iron oxides, lying in what is apparently a devitrified glass. These are probably steam cavities which were formed before the complete solidification of the rock, and into which the still liquid material has soaked and there partly crystallised in the form of felspar and iron ores.

3621 E. *Dyke, Swynnerton Park.* The fine grained chilled margin of the dyke. In this the porphyritic olivines are most conspicuous and perfectly fresh. They enclose magnetite, spinel and rounded patches of the ground mass. The rest of the rock is composed of a very fine grained aggregate of felspar, iron oxides and augite, without flow structure and not subophitic. A small amount of a clear isotropic material is also present, and is probably a pale amorphous glassy base.

3622. E. *Band in Keuper, Swynnerton Park.* This is a calcareous sandstone containing pebbles of *well-rounded* quartz, with a very few of a fine-grained quartzite, and of felspar. There are a few rounded grains of zircon, iron oxide, etc. The matrix is calcareous. Apparently the rock contains very little argillaceous matter, but in places there is a fine siliceous débris, though it is the abundant calcite which forms the principal cementing material. In the calcite there are minute rhombohedra of dolomite.

CHAPTER XI.

SUPERFICIAL DEPOSITS.

Pleistocene and Recent.

A line running roughly north-east from Betton in the south-west, by Norton-in-Hales, Madeley, Wrinehill, Audley, Kidsgrove and Congleton, divides the district into an entirely drift-covered region on the west, and an eastern area in which the Glacial deposits are thin and intermittent. This line of division is determined by the great anticlinal fold, the area of thick Drift roughly coinciding with the low-lying plain of the Keuper Marl on the north-west of that fold. Drift, however, runs up and generally fills the valleys opening to the north and west.

In the central and eastern areas the ice-sheet passed over the entire region; but in this region the Drift is confined to the valleys or to the lesser slopes, and to the flat gathering ground (over 800 feet o.d. on Wetley Moor) or watershed in the north-east corner of Sheet 123. It consists chiefly of clay, but patches of gravel are met with at Carmount Head, and in the Trent Valley between Stockton Brook and Stoke-upon-Trent. There is very little on the high ground between Fenton Park and New Chapel. Little or no Drift is found on the Bunter, but there is reason to believe that a considerable amount of Glacial sand occupies the bottom of the Meece valley between Hatton and Baldwins Gate.

Glacial clays and sands attain a great thickness in the western area. South-west of Buerton they were found to be 101 feet thick in a well 250 yards north-west of Kynsall Lodge, while a little north of Crewe, they have been proved in a boring at Sydney to to have a thickness of more than 320 feet*, thus going down at least 160 feet below sea-level. It is therefore evident that in this part of the western area the Drift fills a deep hollow.

In the western region the Drift consists of every gradation from stiff brown clay to pure yellow sand and gravel. The normal type of the Boulder-clay is a chocolate-brown stiff clay with a small proportion of sand-grains. Frequently, however, the clay contains a considerable quantity of intermixed sand, and what must still be regarded as Boulder-clay, sometimes consists of over 80 per cent. in bulk of sand-grains. The Boulder-clay is entirely devoid of stratification, except for traces of rude bedding in the more sandy varieties. Finely-laminated clays, free from stones, are met with near Crewe and further north, but always at a considerable distance from the margin of the Drift plain. The normal Boulder-clay contains a variable quantity of

* Vert. Sect., Sheet 82, No. 17.

boulders usually small, sub-angular, or well worn, and frequently clearly striated. The Drift-sand is normally a clean, sharp, yellow, stratified sand, often with much current-bedding. It passes through intermediate types of loam and marly sand into sandy clay, and sometimes contains patches or seams of stiff clay and lenticles of coarse gravel.

In certain parts of the district, where the ice has passed over a large surface of rock, the Drift is made up of local material, and it is possible that a considerable amount of such Drift may be present in tracts considered driftless, but it is nearly always impracticable to distinguish it from the product of rocks weathering *in situ*.

It has not been found possible to recognise any definite sequence among the Glacial deposits. The sands and gravels do not seem to hold any fixed position with regard to the clay, neither can an Upper or Lower Boulder-clay be made out. It is probable that clay on sand is the usual sequence. Between the east side of Doddington Park and Checkley Brook a comparatively thin sheet of sand and gravel lies on clay and appears to pass eastward under another bed of clay; but there is no reason to believe that such a sequence is general, and, indeed, any such supposition is negatived by deep borings in which sand and clay repeatedly alternate.

A certain vague system of distribution of the sands and gravels is noticeable on the plains. They tend to run in irregular belts in a north-easterly direction, transverse to the general drainage, but parallel to the outcrop of the solid rock and the axis of the anticline. It seems too that gravel-beds in the sand become less numerous in a direction from the margin towards the interior of the plain. The same may be said both of the included boulders and of the large ones on the surface, as also of the shell-fragments. Current-bedding also is less prevalent in the sand toward the interior of the plain. No such system of distribution exists in the hilly regions where clay preponderates over sand.

In the western area the Drift shows considerable variety of form. It lies in flat or gently swelling plains, or is studded with more or less numerous isolated mounds, while near the eastern margin the surface is thrown up into a chain of low hills of irregular contour. From Betton in the south-west, a narrow belt of low-lying Drift, with a general width of a little more than a mile, flanks the outcrop of the solid rock as far north-east as Onneley. It creeps up the dip-slope of the sandstones, but for the most part is a level or gently-sloping plain, dotted here and there with small mounds. Usually it consists of a sheet of Boulder-clay, which here and there is seen to overlie sand. The mounds are mainly of sand and gravel, often capped with thin clay. Where the Tern Valley at Willoughbridge abuts upon this plain, in the neighbourhood of Willoughbridge and Pipegate, the clay is replaced by a spread of level or gently sloping sand and gravel. At Dorrington and Irelands Cross the Drift is only a

few feet thick, and south of Pipegate it is pierced by inliers of Bunter. A similar belt, composed mainly of Boulder-clay overlying sand, flanks the west side of the anticline of the Coal-measures from Audley to Kidsgrove, but is diversified by ridges of Coal-measures and Triassic sandstones, which reach the surface through it.

West of this belt, from the south-west of the district, a chain of mounds runs north-east through Bellaport and Woore to Onneley, where it impinges against the Bunter tract of Bar Hill, and forms a conspicuous feature as seen from the south-east. This high ground, which may be taken as about a mile in general width, often merges gradually into the drift-plain on its north-west side. It is composed of a great quantity of current-bedded sand and gravel, often lying at the surface over a considerable area, but frequently covered with thin Boulder-clay. The mounds and hillocks are generally elongated in a north-easterly or easterly direction. There is reason to believe that this represents not merely an elevation, but an actual thickening of the drift-sheet near its edge. No trace of solid rock, as far as is known, is found either at the surface or in wells. It is nearly certain that the Glacial deposits rest on Keuper Marl, which may reasonably be expected to be at a lower level than the outcrop of the Keuper Sandstones from Betton to Dorrington. Now the altitude of the summits of the several ridges of Keuper Sandstone between Oakley and Bearstone, decreases north-westwards in the direction of the dip, and also south-westwards along the strike. The most westerly outcrops of sandstone, at three equidistant points, from Norton-in-Hales north-eastwards to Bearstone, are approximately at 360, 380, and 400 feet O.D. respectively. The surface-altitudes of the high drift-ground at corresponding points from south-west to north-east, at about one mile's distance from the outcrop of the rock, are respectively 490, 520, and 553 feet, giving a probable minimum thickness of from 130 to 153 feet for the Drift, on the assumption that the beds on which it rests lie no higher than the outcrops of the Keuper Sandstones on the south-east. If the thickness of 101 feet of Glacial material obtained south-west of Buerton is any criterion of its general thickness in that part of the plain which lies immediately to the north-west, this would show a considerable thickening of the Drift near its margin. But the mere fact that a belt of Drift resting presumably on Keuper Marl, rises to an elevation of 130 or more feet above the nearest outcrops of sandstone, is in itself evidence of a local thickening. This chain of Drift-hills was regarded by the late Carvill Lewis as a terminal moraine; but, as it has been stated above, current-bedded sand and gravel make up the bulk of it.

Further north a broad ridge, composed of sands and gravels partly covered with clay and resting on Keuper Marl, extends from Foxley to Alsager. It rises to an altitude of only 30 or

40 feet above a comparatively narrow valley, which separates it from the sandstone features, and may be of similar origin to that previously described.

On the north-west side of this zone of high ground, a broader tract of low-lying Drift, from one to two miles in width, runs in the same north-easterly direction from Highfields by Buerton, Woore Flash, Checkley, Wrinehill, Betley, Balterley, and Barthomley. It is for the most part a level plain with few mounds and hillocks, and lies at an altitude of about 300 feet O.D. It is almost entirely covered with Boulder-clay, though diversified here and there with patches and mounds of sand. Frequently the clay is only a few feet thick. This tract is intersected by the valleys of Checkley Brook and Betley Mere, in which sand is seen to underlie the clay,

Again on the north-west side a broad, irregular belt, in which sand predominates, runs also in a general north-easterly direction from north of Buerton, through Doddington, and west of Barthomley and Alsager. Though not rising into conspicuous hills its surface is more varied with gently swelling hillocks and mounds than that of the neighbouring clay tract; it also occupies for the most part somewhat higher ground.

The prevalence of current-bedding in the sands and gravels, and of lamination in certain clays in the interior of the plain, contrasted with the total absence of stratification in the normal Boulder-clay, shows that the sands, gravels and laminated clays were deposited under conditions different from those which produced the Boulder-clay; and points to the accumulation of the sands and gravels by the action of torrents, and the deposition of the laminated clays in stiller water.

Boulders of all sizes up to 10 feet or more in length are abundant, but especially towards the margin of the Drift-plain. The largest are found on the driftless area, particularly round Beech, but some of the biggest occur east of Bucknall, one in the stream course north of Little Brookhouse Farm being over 12 feet in length and 8 feet across. The boulders probably include examples of all the principal intrusive masses of the Lake District; also of the Borrowdale volcanic series, chiefly from the fragmental rocks of the central mountains. The intrusive rocks consist mainly of Eskdale granites, Buttermere granophyres and white granites from the South of Scotland. The Criffel granite, however, has not been recognised. A red rock full of green acicular augite is abundant chiefly in the south of the district. It resembles a local modification of the Eskdale and Carrock rocks; but the latter in its normal phases is not common. Volcanic boulders include basalts with porphyritic augites, streaky garnetiferous lavas, metamorphosed amygdaloidal basalts, and rocks resembling the Westmorland rhyolites. Rocks from South Scotland are well represented on the high ground round

Keele, Maer and Hanchurch, but are also common on the Drift-plain to the west. Rocks from Wales may be represented by some compact felsitic boulders which correspond very well with the lavas of Arenig. A grit closely resembling the curious rock of Ingleton is met with among the large number of boulders near Shelton-under-Harley. Red and grey flints are occasionally found, and may be derived from the concealed Secondary rocks to the north-west. West of Norton-in-Hales two boulders were noted, which there is little doubt belong to the Rhætic. This is of interest in view of the well-known occurrence of Lias at Audlem.

Fragments of marine shells have been found in many places. They are most abundant towards the margin of the Drift-plain, but less numerous, at any rate in the sands and gravels, towards the interior. Though observed more frequently in gravel and sand than in Boulder-clay, it is probable that this is owing to the comparative scarcity of unweathered sections in the latter, and the bad state of preservation of the shell-fragments in it. It is probable that on the margins of the plain these shell-fragments are almost ubiquitous in the clay, but widely scattered and seldom numerous in any one spot. On the other hand in gravel and sand they are often abundant in one section or even in one seam of gravel, though apparently absent in neighbouring sections or seams. They are especially common in the gravel lenticles. The shell-fragments seem to have been transported, the edges being well worn and the surface sometimes minutely striated. Amongst numerous specimens submitted to him for examination Mr. Clement Reid has identified the following:—*Balanus sp.*, *Trophon ?*, *Turritella terebra* (Linn.), *Astarte sulcata ?* (Da Costa), *Cardium edule* (Linn.), *Cardium sp.*, *Cyprina sp.*, *Mya sp.*, *Mytilus sp.*, *Tellina balthica* (Linn.). These, as pointed out by Mr. Reid, belong to a shallow-water fauna, and are not indicative of very cold conditions. By far the greatest number of fragments belong to *Cardium* and *Tellina*, but *Turritella* is also abundant.

A large part of the Biddulph Valley is entirely free from Drift. The distribution of the thicker Drift of the valley follows the course of the Biddulph Brook upwards and southwards from the wide gap in the grit-ridge on the north-west side of the basin at Mossley. The extreme north end of the synclinal Coal-measures, on higher ground, is driftless; but southwards from the above-mentioned gap Glacial deposits spread thickly over the bottom of the hollow and evidently obliterate an old drainage channel, for the present stream-course is post-glacial. Drift extends up the slopes approximately to the 600-foot contour in the northern part of the valley, thinning out southward; till beyond Bradley Green it is restricted to the lower ground, with the exception of thin ragged remnants on the higher slopes to the south and west. Northwards from Bradley Green to a

short distance beyond Biddulph it is frequently cut through in the main stream-valley and the railway cuttings. At a point less than 300 yards north of the Lea Mill Forges, on the north side of Biddulph, shale is just exposed in the brook under about 35 feet of Drift, chiefly sand. Probably even in the lowest part of the basin further north the thickness of the Drift is not much more than this, though solid rock does not appear again at the surface At the point above-mentioned the apparent thickness may possibly have been exaggerated by slipping, as the Drift overlies shales dipping towards the stream. West and north-west of the village of Biddulph the drift-covering has evidently been sufficient to prevent the discovery and surface-working of the lower coals in former times, though on the east side of the valley this has not been the case, and the Crabtree and Little Row coals have been found in spite of the mantle of Glacial sand and clay.

West of the anticline, Drift covers the lower slopes of the Coal-measures north of Hall o' Lea. A spread of sand obscures the measures west of the outcrops of the Bambury Coals and doubtless accounts for the fact that immediately south of the Bank the higher seams have not been worked at the surface as have the Seven Feet Bambury and lower coals a little further east. This sand is probably nowhere much more than 12 feet thick.

Further north the thicker Drift of the lower-lying western region thins out against the rising ground west of Quarry and Grotto Woods, running somewhat higher up the slope south of the old Lime Works. It overlies the shales above the Carboniferous Limestone at Astbury Quarry, and sweeps up nearly to the 700 foot contour-line and the outcrop of the Third Grit on Congleton Edge, against the northern end of which Drift-sand is banked.

Along the stream-course of Dane-in-Shaw the Drift is seen to be still somewhat thin, as the red Keuper Marl is exposed in the banks at frequent intervals. In this valley the Glacial sands and clays are probably seldom much more than 20 or 30 feet thick, though this thickness may increase somewhat as the ground rises away from the valley on either side. Here, as in the Biddulph Valley, sand is usually seen to be overlain by Boulder-clay.

The Drift, both within and immediately west of the Biddulph Valley, consists largely of clean sand, with lenticles and patches of gravel and clay, and is often overlain by thin red Boulder-clay. In the thicker part of the Drift-deposits in the valley whenever good sections occur, sand, when not actually at the surface, is usually seen to be present in or under the clay, and it is doubtful whether any part of the thicker Drift here consists entirely of Boulder-clay.

That the sand of the Biddulph Valley is of similar origin to that of the Drift-plain to the west, is indicated by the occurrence in it of the same small marine shell-fragments at the sandpits near Gillow Heath Station. The Boulder-clay is red or brown and often sandy, with the usual north-country plutonic and volcanic boulders, and a large admixture of local rocks.

The thicker accumulation of Glacial Drift in the lower and northern part of the valley, and in and about the gap in the grits at Mossley on the north-west side of the valley, shows that the Drift entered largely, though probably not solely, by way of this gap; through which it is gradually being washed out again by denudation.*

Alluvium, Peat.—The alluvial deposits of the Pottery Coalfield are insignificant. The chief points of interest have been mentioned in dealing with the River Systems (pp. 5–12).

The hollows between the Drift-mounds in the western area are frequently occupied by peat. These peat-filled hollows either lie in sand or are associated with large sheets of sand underlying thin Boulder-clay. The peat is often of great thickness, as at Betton Moss, Cracow Moss (near Betley), Oakhanger and White Mosses (near Alsager), and Craddock's Moss. The brown peat of White Moss is extensively worked for litter.

* The Glacial deposits of the Pottery Coalfield have for many years received the close attention of Mr. F. Barke. Quite recently (*Trans. North Staffs. Nat. Field Club*, vol. xxxviii., pp. 111–117. 1904) Mr. Barke has drawn attention to the occurrence of Drift at several places within the coal-field, where it is not indicated on the Drift Edition of the Map (Sheet 123, N.S.). This is more especially the case on the ground between Cliff Bank and Oakhill, Stoke; and around Wolstanton, Burslem, and Tunstall.

CHAPTER XII.

ECONOMIC AND APPLIED GEOLOGY.

By W. Gibson.

The rocks and minerals of economic value other than coal have been incidentally mentioned in the account of the various formations in which they occur, but rather from a geological than economical standpoint.

Each mineral will now be separately described in its economical aspect; and after this the chief sources of the water supply will be treated of.

Coal.

As will be gathered from the account of the Coal-measures, this mineral forms the chief product of the North Staffordshire Coalfields. The area of the exposed coalfield of the Potteries, excluding a large portion occupied by the Keele Group (Permian, previous to the re-survey), amounts to about 75 square miles. Including seams over two-feet in thickness, the total thickness of coal amounts to over 140 feet. Until within recent years the coal has been obtained at depths under 2,000 feet, and a large quantity of the coal at the present day comes from well under this depth. Between 1861 and 1880 the output rose from 2,372,000 tons to 4,074,800 per annum. Between 1880 and 1890 the amount never exceeded 5,000,000 tons. Since 1892 the following table shows the fluctuation of output:—

Year.	Output in tons.
1892	5,004,844
1893	4,962,189
1894	4,954,341
1895	4,613,640
1896	4,788,390
1897	6,434,197
1898	6,652,545
1899	6,799,237
1900	5,601,759
1901	5,565,626

A considerable portion of the coal raised is consumed in the numerous local industries, of which the most important are the ironworks, potteries and brick manufactories. The gas coals are largely exported; the city of Birmingham obtaining a large quantity from the Talke area.

The following tables gives the difference in analyses of the two main classes of coal met with in the district.

ANALYSES OF GAS AND COKING COALS.

	TEN FEET COAL SILVERDALE.*	FOUR-FEET COAL, APEDALE.*
Volatile matter	34·0	40·0
Coke	66·0	60·0
Ash (in coal)	1·95	·75
„ (in coke)	2·95	1·25
Sulphur (in coal)	1·30	·80
„ (in coke)	0·70	·38
„ (in volatile matter)	0·60	·42

ANALYSES OF NON-COKING COALS.†

	LITTLE ROW.	OLD WHIT-FIELD.	BOWLING ALLEY.	HOLLY LANE.	HARD MINE.
Fixed Carbon -	61·59	61·27	63·13	61·79	63·50
Volatile Hydro-carbons -	37·40	37·61	31·70	37·35	34·85
Sulphur -	0·20	0·12	0·62	0·06	0·00
Ash -	·81	1·00	4·55	0·80	1·65.

The thickness of the individual seams and the uses to which they are put have been given in previous chapters.

According to the report of the Royal Commissioners (1871), the Pottery Coalfield has an area of 30,876 acres within the outcrop of the Keele Beds (Permian) and Trias on the south and west, and the New Red Sandstone and Millstone Grit on the east. The total quantity of coal available after deducting portions likely to be sacrificed by faults, barriers, and loss in working was estimated by the Commissioners to be 2,338,341,053 tons at depths not exceeding 3,000 feet, and an additional 564,928,888 tons for depths between 3,000 and 6,000 feet. The report, however, does not give any data as to the amount of cover estimated to overlie the seams above the Red Shagg Coal, the highest of the seams; but certain horizontal sections accompany the report which demand consideration. Thus in section No. 18, pl. 3, the Red Shagg at Newcastle-under-

* *Colliery Guardian*, vol. lxxxv., 1903, No. 2197, p. 300.
† Chas. Homer. *Proc. Iron and Steel Inst.*, 1875, p. 340.

Lyme is represented as being about 1,300 feet below the River Lyme. The Keele Beds here exceed 100 feet; to this about 1,800 feet must be added for the Newcastle, Etruria Marls and Black Band sub-divisions, thus making the Red Shagg 1,900 feet beneath the surface. Further west in the same section the Keele Beds (Permian of the section) are represented as unconformable to the Coal-measures and reposing on the Black Band Group; the Bassey Mine at a spot a few yards east of Over Bitters Wood being shown as about 1,000 feet beneath the surface, whereas in reality it approaches 2,000 feet. In section No. 17, the evidence now obtainable at Moddershall Oaks (p. 126) hardly warrants the position of the coals or structure of the ground represented. In section No. 16 the Keele beds (Permian) are again represented as being unconformable to the Coal-measures, though the depth to the Red Shagg as drawn is probably not far from the truth.

The question as to the future available supply, will now be discussed.

Future Development of the Coalfield.

Before dealing with this important economic question it will be necessary to refer to the main geological features of the Pottery Coalfield. As we have seen, the Carboniferous strata have been thrown into three main folds, consisting of an eastern and western anticline enclosing a central syncline, which includes the major portion of the coalfield. These folds converge in the north, while in an opposite direction they rapidly diverge till the two anticlines lie over nine miles apart. The eastern anticline brings up only the unproductive portion of Carboniferous rocks so does not concern us; the western anticline terminates abruptly on the line of a great disturbance, which we have termed the "Western Boundary Faults," (p. 175). The question of the future coal resources of the district can therefore be conveniently considered under two heads; the supply underlying the surface to the west of the Boundary Faults and that remaining untouched to the east of these faults, of which that existing in the central portions of the syncline is the most important.

Supply to the east of the Western Boundary Faults. The outcrop of the Bassey Mine Coal separates the area occupied by the Grey Chief Coal-bearing Series, of which the amount of coal remaining can be fairly satisfactorily determined, from that of the well-defined region occupied by the Red and Grey Series. The latter occupies an area of about 40 square miles, of which the greater portion overlies coal-measures from which few of the seams have been touched. Considering that the coal-bearing strata contain about 140 feet of workable coal and several valuable bands of ironstone the untouched wealth of the coalfield would seem to be enormous. Mining experience in the coalfield shows the general absence of washouts and the

persistence of the seams over the area; the question then remains of ascertaining the depths to the seams beneath each group covering this large tract of virgin ground. (Fig. 2, p. 15.)

Within the outcrop of the Black Band Group a considerable quantity of the seams above the Bassey Mine has been extracted in conjunction with the ironstones; vertically beneath this coal down to the Ash Coal less has been withdrawn; while of the important seams below the Ash nearly the whole remain intact. The depth to the Ash Coal within the outcrop of the Blackband Group lies between 1,000 and 1,400 feet, from which the approximate depth to the deeper-seated seams can be readily calculated from the section (p. 61).

Beneath the wide spread of Etruria Marls there are no collieries working the seams below the Ash Coal excepting the Florence Colliery in the south-east, and the Glebe and Oldfield collieries. The Longton Hall Colliery and the Rowhurst Pits of the Shelton Colliery have attacked the seams between the Ash and the Bassey Mine. The seams above the Bassey Mine have been more extensively worked, but large areas remain untouched. Here, then, there lies a large body of coal well within the present theoretical limit of workings. The great thickness of the Etruria Marls (800 to 1,100 feet) must, however, be kept in mind. Supposing a shaft to commence towards the summit of the group, this would reach the Bassey Mine between 1,100 and 1,500 feet, and the Ash Coal between 1,800 and 2,400 feet, the lower estimate holding for the south-eastern portion, the higher figures for the central portion. In the Newstead boring (Sect. No. 1, Appendix III.) 1,112 feet separate the Bassey Mine from the base of the Newcastle-under-Lyme sub-group, estimated and proved thickness thus agreeing very closely. We may here refer to areas occupied by the Etruria Marls, of which the importance does not seem to us to have received sufficient local attention. The first of these is the strip lying between the Newcastle and Apedale Faults in the Lyme Valley between Newcastle-under-Lyme and Hanford. A shaft commencing in the alluvium of the Lyme near Trent Vale should reach the Bassey Mine at a depth not exceeding 1,200 feet. Another tongue of Etruria Marls extends between Silverdale and Shutlanehead on the upthrow side of the Apedale Fault. A shaft situated on the west side of the Seabridge Road south of Hands Wood might be expected to reach the Bassey Mine at 1,100 feet. Between Madeley Heath and Madeley Village the Etruria Marls probably crop out underneath the Glacial deposits, but the ground is necessarily obscure, and in the neighbouring driftless areas there are indications of faulting, though of an obscure character. The maximum depth to the Bassey Mine should not exceed 1,200 feet, and may be less, as the outcrop of the marls is at the southern end of the western anticline. On the other hand, we must allow for possible faulting.

Since the thickness (300–400 feet) of the Newcastle-under-Lyme Group varies little over the district, there is no

necessity to calculate the approximate depth of the seams, which can be readily arrived at by adding this thickness to the previous estimates.

Within the broad outcrop of the Keele Group any definite calculation is prevented owing to the thickness of the beds at present being unknown. At Trentham we know that the Bassey Mine lies 1,946 feet beneath the surface where the Keele sub-group was 552 feet thick and the Etruria Marls under 800 feet thick. North of Newcastle-under-Lyme, towards the centre of the syncline, we know that each sub-division has increased greatly in thickness, and we are probably not wrong in giving 2,500 feet for the depth to the Bassey Mine a little north of Knutton. (See Fig. 18, p. 210.)

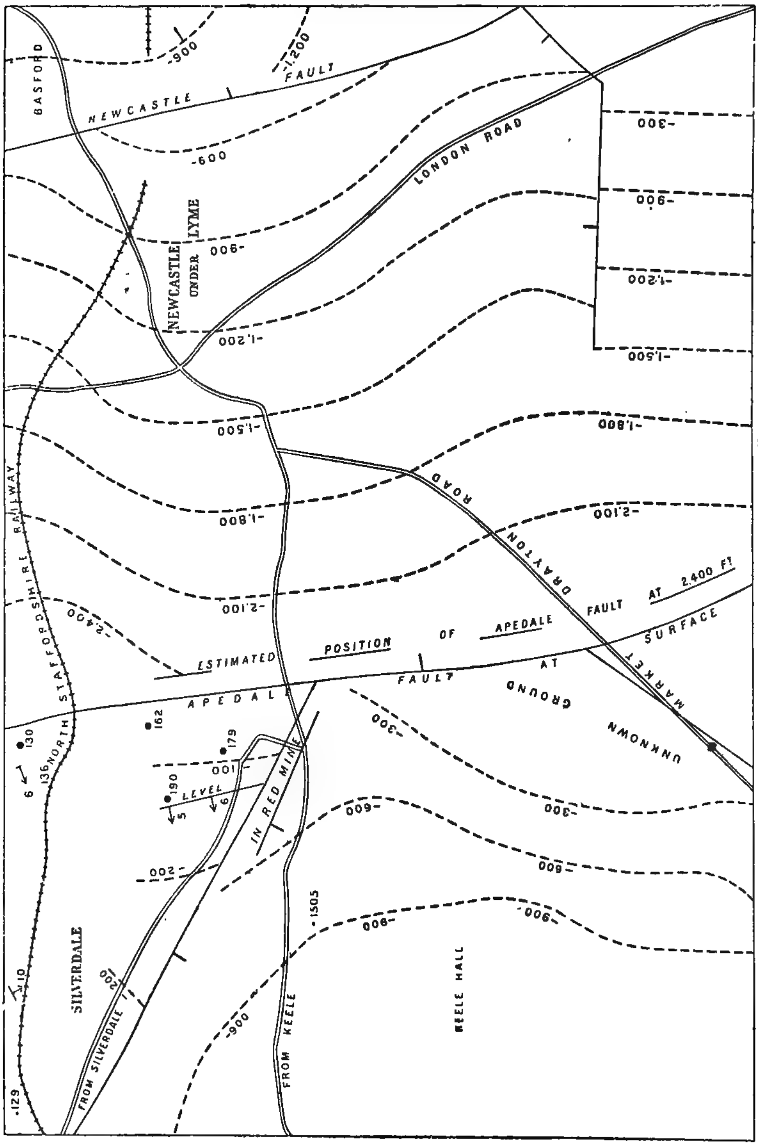
Supply to the West of the Boundary Fault.—On the western side of the Staffordshire anticline, which boldly faces the Cheshire Plain, the workable coal seams are steeply inclined westward in their upper workings, but traced westward they rapidly flatten out as they approach the "Boundary Fault." On the downthrow side of this large fault or belt of disturbance, of which the total displacement does not probably fall short of 800 yards (p. 177) the Etruria Marls, Newcastle-under-Lyme, and Keele sub-divisions crop out between Heighley Castle and Audley. The few places where the inclination can be observed indicate that this does not exceed 10 degrees to the west or south-west, in which direction the beds can be followed for nearly a mile. They then become hidden under Drift through which the Triassic rocks emerge at Millend, Coopers Green, and Knowle Bank. Northward we know the junction of the Trias and Coal-measures to be a fault (Red Rock Fault, p. 187), while southward, between Bearstone and Oakley, the Trias is much cut up by faulting. Since faulting in the Trias frequently follows along the lines of older and often more powerful fractures, the scanty evidence afforded by surface exposures would seem to indicate that west of Audley the extension of the coalfield in this direction would be limited by a belt of disturbed ground.

Between this uncertain ground and the Boundary Fault an area of Coal-measures about three square miles in extent undoubtedly exists, under which the Pottery Bassey Mine would be between 650 and 1,000 feet below the surface and the Bullhurst Coal a little over 3,000 feet. Little is known of the Blackband ironstones, or of the seams above the Ash Coal on the west side of the anticline so that these may not prove to be of such value under the area under discussion as they are within the central portions of the coalfield; but the seams below the Ash Coal are of great value on the anticline, and many of these it will be gathered from the estimated depth to the Bullhurst Coal lie well within workable depths. (See Fig. 2, p. 15.)

North of Linley Wood the Red Rock Fault becomes the dominant factor in determining the extension of the coalfield

FIG. 18.

Map shewing underground Contours of Red Mine Ironstone in feet below O.D. around Newcastle under Lyme. Figures against black circles shew the proved depth in yards from surface of the Red Mine. Figures 1505, north of Keele Hall shew depth to Red Mine in feet proved in Bore Hole.



Scale two inches = one mile.

westward. Unfortunately we know next to nothing about the amount of throw or hade of the fault (p. 188), but all the available data point to its being a fault of large throw at least in the Carboniferous rocks.

There is good reason to believe that the Red Rock Fault increases northward, and may in this way counteract any northerly decrease in throw of the Boundary Fault, so that west of the Moss Pits the limiting fault may amount to between 500 and 600 yards. Between the Moss Pits and the Bank on the upthrow side of the fault the chief coals from the Bullhurst up to the Four Feet Seam crop out, the highest seam close to the fault. The character of the higher seams and thicknesses of the intervening measures is not definitely known in the northern section of the anticline, excepting for a short distance above the Birchenwood Coal of the Bath pits; but by piecing together the different shaft sections we may estimate that about 500 yards of strata separate the Bee Coal of the Birchenwood Colliery from the Bullhurst. Consequently, if the limiting fault amounts to this displacement the Bee Coal would be brought against the Bullhurst in an extension westward of the workings of this seam in the Moss and Hall o' Lea Collieries. It may reasonably be expected that, on the downthrow side of the fault, the seams would rapidly flatten out just as they do along the whole length of the anticline southward.

The fault may, however, exceed 500 yards and the overlying Trias be of considerable thickness. On the whole, regarding our absolute ignorance of the main data on which any calculations can be safely made, we hesitate to offer any opinion and have only touched upon the subject with the hope that this important and frequently-discussed problem will be settled by one or more of the collieries situated close to the fault.

*On the Prospect of Finding Coal near Congleton.**—Though the Red Rock Fault between the Moss Pit and The Bank limits the coalfield by throwing down the measures on the west; yet it is possible that further north, beyond where the lowest Coal-measures have cropped out, this same fault may have helped to preserve, and bring within reach a part of the Coal-measures on its western side. But in the present state of our knowledge it cannot for a moment be maintained that there is any ground for assumption that such is actually the case. Still, such facts as we have, point to a reasonable possibility of the occurrence of some of the principal coals under the Red Rock, sufficiently near the surface to repay working.

The Western or Staffordshire anticline, traced at the surface beyond the old limestone-quarry at Astbury in a north-northeast direction, pitches down both southwards and northwards from this point, so that in the latter direction the dome of lime-

* By C. B. Wedd.

stone seen in the quarry has passed under shales in the stream by the roadside a short distance north of it. West of the north end of Congleton Edge at Mossley higher shales between the Millstone Grits and the Carboniferous Limestone reach the surface with north-westerly dip.

Up to this point the Red Rock Fault lies on the west side of the anticline, close to its crest. It must very shortly cross the saddle at Mossley, or run along its crest, if the fold has not died out, for the fault comes close up to the Third Grit dipping south-east in Rainow Hill. It is possible that the fault may terminate the anticline, but this is not likely considering the magnitude of the fold, and the continuance of the complementary Biddulph syncline further north than Cloud Hill. It may be expected then that the saddle continues for some distance north of Mossley partly or wholly on the west side of the fault, under Trias, and that in any case the thickness of the rocks of that system will diminish as they approach the Carboniferous uplift. For besides being faulted down against strata of this age, the Red Rock was probably first banked up against the rising ground of the Carboniferous.

As the fault approaches close to the outcrop of the Third Grit, beds higher than that grit were thrown down to its level on the west—how much higher beds, depends on the amount of displacement in the fault, which is unknown. The throw may be expected to be somewhat large, even in the Trias, for the fault runs for many miles, and throughout its course throws down Triassic against Carboniferous rocks. It is most likely that the line of fracture is one along which movement took place both before and after the deposition of the Red Rock; so that in this event the Carboniferous beds on the downthrow side would show a greater displacement than the Triassic. A throw of 600 yards, which is less than the greatest displacement of the Apedale Fault or of the Western Boundary Fault further south, would bring down a horizon above the Winpenny Coal to the level of the Third Grit. It may be said that, the greater the throw of the fault, the greater will be the probability of the occurrence of coal on the west side of it, the greater too the number of seams represented, but the greater also the difficulty of reaching them, if the displacement affecting the Trias is also large.

If then, as is probable, the anticline, though diminishing northwards, still persists west of the fault, such coal-bearing measures as may have been thrown down under the Trias, should have an easterly or south-easterly inclination close to the fault, but should bend over in the saddle, off which they might be denuded entirely, and should crop out round the northern end of the anticline in horse-shoe shape, where they might be expected to dip westward towards Congleton. If, however, the fault coincides with the axis of the anticline, then only westward-dipping Coal-measures could occur in the western limb of the fold and the

area in which a given seam of coal might be within reach, would be somewhat less.

The thickness of the Red Rock must now be considered. To determine this, few data exist. In the Maypole Dairy Company's boring near Congleton Station about 960 feet of Red Marl, including some Drift in the upper part, was passed through without reaching the base of the Keuper Marl, whilst the lowest beds in the bore-hole still consisted of marl with gypsum. It is quite likely that below this there still lies a considerable quantity of Keuper Marl, but it is also most likely that whatever the thickness of the Trias here, it will diminish somewhat eastwards towards the rising Carboniferous ground. It is by no means certain that anything like the full thickness of Triassic sandstones beneath the Keuper Marl would have to be passed through before reaching productive Coal-measures, since the Red Marl may not improbably overlap the Triassic sandstones eastwards to some extent. West of Mow Cop, the Keuper sandstones are probably thin, but the thickness of the Bunter is unknown. The nearest outcrop of the latter to the bore-hole is north of Mow Cop, about two-and-a-half miles distant; the average dip is sure to be a comparatively small one, and in a general north-westerly direction rather than directly towards the bore-hole. This suggests that the top of the Bunter lies at no great depth below the point reached in the bottom of the Maypole Dairy borehole.

A section of an old boring on the Howford Bridge Estate, Buglawton, near Congleton, below 118 feet, which certainly must belong to the Keuper Marl inclusive of Drift, continues nearly 50 feet lower in rocks in the description of which such terms as "black bass," and "grey bass shale," appear.* It is difficult to see how these terms could be applied to any beds in the Trias, and the section suggests the occurrence of Carboniferous strata at a depth of only 118 feet, at a point somewhat nearer to the Red Rock Fault, than the Maypole Dairy bore-hole is. It is, however, uncertain how much reliance can be placed on the section.

Ironstones.

By W. GIBSON.

The Coal-measures of North Staffordshire are especially rich in iron ores, still largely used in the manufacture of pig-iron but not to the extent the great capabilities of the coalfield would lead one to expect. The decrease in output from 1,783,000 tons of ore raised in 1884 to 776,363 tons raised in 1902 has mainly arisen from the importation of cheaper ores.

The ironstones fall naturally into two classes occupying a constant position in the Coal-measure sequence. Those in the

* See Sect. No. 69 Appendix, also *Mem. Geol. Surv.*, Geology of the Country round Stockport, Macclesfield, Congleton, and Leek, p. 41.

Blackband subdivision are laminated ores of the variety known as Blackbands; those below are classed as Clay-ironstones and are more numerous above the Ash Coal. In addition the Chalky Mine Ironstone above, and the Burnwood Ironstone below the Ash Coal, are distinctly laminated clay-ironstones and are sometimes spoken of as semi-Blackbands. In former years considerable quantities of Clay-ironstone were raised, but lately the Blackbands and semi-Blackbands have met with most favour. In the Pottery Coalfield the lowest ironstone of any consequence is the Burnwood, but in the adjacent Cheadle Coalfield a calcareous hæmatite, known as the Froghall Ironstone and lying a few feet above the First Grit, was extensively worked and practically exhausted towards the middle of last century.

Clay Band Ironstones.

Character and Occurrence.—The clay ironstones are compact, fine grained, extremely hard, nodular, argillaceous carbonates of iron, void of lamination except the semi-blackband varieties. They occur in bands and nodules (chance bands). The larger nodules frequently contain irregular branching cracks, filled with greyish-white hydrated silicate of alumina and carbonate of lime containing crystals of zinc blende, galena, and iron pyrites.

The following table shews their order of occurrence in the two areas.

TABLE SHEWING THE OCCURENCE OF THE CLAY BAND IRONSTONE.

WESTERN AREA.	EASTERN AREA.
Black Bass Ironstone.	
Cannel Mine Ironstone.	
Gubbin Mine Ironstone.	Gubbin Mine Ironstone.
Sheath Mine Ironstone.	Cannel Row Ironstone.
Black Stone Ironstone.	Wood Mine Ironstone.
Rusty Mine Ironstone.	Pennystone Ironstone.
Chalky Mine Ironstone.	Deep Mine Ironstone.
Little Mine Ironstone.	Chalky Mine Ironstone.
New Mine Ironstone.	New Chalky Ironstone.
Brown Mine Ironstone.	Hanbury Measures.
Thick Band Ironstone.	Ragmine Ironstone.
Gold Mine Ironstone.	Priorsfield Ironstone.
	Knowles Ironstone.
	Black Mine Ironstone.
	Brown Mine Ironstone.
	New Mine Ironstone.
Burnwood Ironstone.	Burnwood Ironstone.
Top Two Row Ironstone.	

The table does not attempt to show the correlation of the seams in which much work remains to be done. It is probable that the Rusty Mine of the western area is the equivalent of the Pennystone Ironstone of the eastern area; while the Burnwood Ironstone is most likely on the same horizon in both districts.

The Two Row Ironstone occurs in the western area and was worked in conjunction with the Two Row Coal. The following section shows its position at Silverdale.

TOP TWO ROW IRONSTONE AT SILVERDALE.

From Mr. J. C. Cadman.*

	Ft.	In.
IRONSTONE, containing *Carbonicola*	3	6
Bass with chance bands	2	0
IRONSTONE	0	3
Bass	0	8
IRONSTONE	0	4
Bass	1	6
TOP TWO ROW COAL	2	6

At the Nabbs Pit, Silverdale, the ore contains 20·77 per cent. of metallic iron.

Burnwood Ironstone.—In the Longton district this is known as the Little Mine Ironstone. It lies in bands with partings of bass, and averages one foot three inches to one foot six inches thick. It is a semi-blackband and is being raised in the eastern area. The underlying coal is used for manufacturing purposes.

SECTION OF BURNWOOD IRONSTONE, CHELL DISTRICT.

	Ft.	In.
Bass		
IRONSTONE	2	4
Press shale, 2 inches to	1	6
IRONSTONE	1	5
COAL	0	8

SECTION OF BURNWOOD IRONSTONE, FENTON DISTRICT.

	Ft.	In.
Bass		
IRONSTONE	0	4
Bass	0	8
IRONSTONE, Chance	0	3
Bass	0	3
IRONSTONE, Lean	0	6
Bass	0	6
IRONSTONE, Chance	0	3
Bass	0	4
COAL	2	4

New Mine Ironstone.—About one foot four inches thick and lies immediately above the Burnwood.

* The table, p. 214, and the following sections will be found in *Trans. Inst. Min. Eng.*, vol. xxii., pt. 1, pp. 88–89, 1901.

Gold Mine Ironstone.—Only recognised in the western area, where it varies considerably in thickness and quality.

SECTION OF GOLD MINE IRONSTONE, HOLLYWOOD PITS.

	Ft.	In.
Black shale with chance bands		
Grey shale	1	3
IRONSTONE	0	4
Grey shale with nodules of ironstone	1	0
IRONSTONE	0	8
Grey shale	0	6

Brown Mine Ironstone.—This seam has been extensively worked in the western area. The lower bands are often semi-blackband. The overlying coal is of poor quality and is left in the mines, as it forms a good roof.

SECTION OF BROWN MINE IRONSTONE AT KENT'S LANE.

	Ft.	In.
COAL	4	0
Bass	3	0
IRONSTONE	0	8
Bass	0	6
IRONSTONE	0	3
Bass	0	5
IRONSTONE, Blackstone	0	8
Bass	0	6
IRONSTONE, 4 inches to	0	8

Knowles or Winghay Ironstone.—The ironstone of this name occurs only in the eastern area, its representative on the west being uncertain. The Priorsfield Ironstone was extensively worked by open cast in the Longton district.

Chalky Mine Ironstone.—In colour dark brown to greyish black; compact; contains minute crystals of zinc blende. Entomostraca common. Varies in thickness from one foot six inches to two feet six inches, and yielding 2,900 tons per acre. The section in the western area is as follows:—

SECTION OF CHALKY MINE IRONSTONE AT HOLLY WOOD.

	Ft.	In.
IRONSTONE	0	4
Black shale, roof	3	0
Black shale with chance bands of ironstone	1	1
IRONSTONE, Hussle-band	0	5
Black shale	0	3
IRONSTONE, Lean	0	9
Coal	2	0

In the Clanway Colliery, Tunstall, the stone is underlain by a grey nodular ironstone, rich n iron, as shewn by the following analysis, but with too high a percentage of silica to render it

worth getting, though it is necessary to extract it together with the Chalky Mine.

ANALYSIS OF CALCINED ORE OVERLYING THE CHALKY MINE,*

CLANWAY COLLIERY, TUNSTALL.

SiO_2	22·75 per cent.
Al_2O_3	10·96
Fe_2O_3	39·80
FeO	17·31
MnO	1·70
CuO	trace
(Ni,Co)O	·07
BaO	·06
CaO	3·80
M_gO	2·98
P_2O_5	·75
S	·07
H_2O	·12
Total	100·37

Metallic Iron, 41·32.

Sheath Mine Ironstone.—This ironstone has been extensively worked in the Silverdale area, where the section is as follows :—

SECTION OF SHEATH MINE IRONSTONE AT KENT'S LANE.†

	Ft.	In.
Hard black shale, roof		
IRONSTONE	0	3
Grey shale	0	2
IRONSTONE, Lean	0	11
Grey shale	0	2
IRONSTONE	0	3
Grey shale	0	8
IRONSTONE	0	4
Fireclay	3	4

Deep Mine and Pennystone Ironstone.—The Deep Mine at Longton was a favourite ore. It varies in colour from brown to greyish black. It is compact and homogeneous and frequently crossed with veins containing a hydrated silicate of alumina and carbonate of lime. It also contains minute crystals of zinc-blende and copper pyrites. The occurrence at Fenton Park Marl Pit of nodules of spherulitic siderite containing 38·7 per cent. metallic iron has been noted on p. 71. The Pennystone Ironstone of Shelton possesses similar characteristics to the Deep Mine.

Cannel Row Ironstone.—This is associated with strong cannel once used for oil making, when it yielded according to Mr. Charles Homer ‡ from 50 to 60 gallons of crude oil per ton of ·870 specific gravity. The residual product of distillation is a fair blast furnace ironstone.

* Analysed by Dr. Pollard in the Survey Chemical Laboratory.
† *Op. cit.*
‡ Proc. Iron and Steel Inst., p. 18, 1875.

Gubbin Ironstone.—A valuable clayband seam from 1 foot to 2 feet 2 inches lying in 3 feet to 4 feet of bass. In the Apedale area it is a dark grey compact stone, intersected with thin veins of carbonate of lime.

ANALYSES OF CLAY IRONSTONES.

	Cannel Row.†	Gubbin.*	Pennystone.†	Deep Mine.†	Chalky Mine.†	Winghay.*	Rusty Mine.*	Brown Mine.*	Burnwood.*
Protoxide of Iron	41·80	38·85	46·35	48·33	51·07	58·46	40·37	41·15	43·25
Peroxide of Iron -			3·00					1·84	
Protoxide of Manganese -	2·16	2·04	1·61	2·99	2·36	0·01		1·40	
Alumina -	0·53	5·71	0·30	0·41	0·54			0·60	
Lime - -	5·07	2·52	1·93	1·52	1·74	2·65		4·00	
Silica -		10·50				0·08		13·80	
Magnesia - -	3·03	1·13	2·24	1·19	1·10	1·02		1·65	
Carbonic Acid -	32·40	28·24	32·46	32·76	33·63	34·55			
Phosphoric Acid -	1·40	2·76	0·67	0·87	1·12	0·40		1·82	
Sulphuric acid -	trace		trace	trace	trace			0·31	
Bisulphide of Iron	0·04	0·80	0·15	0·19	0·17	1·62			
Water (hygroscopic) - - -	0·36								
Water (combined)	0·71	3·25	1·43	0·85	0·99	0·13			
Organic matter -	0·79	4·20	2·95	1·17	1·24	0·61			
Ignited Insoluble Residue - -	10·81		7·29	9·28	5·18				
Loss on Ignition -								33·84	
Total - -	99·10	100·00	100·38		99·14	99·53		100·41	
Iron total amount (Raw stone)	32·64	30·60	38·29	37·83	39·88	46·51	31·40	33·29	35·20
do. (calcined) -	50·61	45·97				68·80	46·62	48·33	52·03

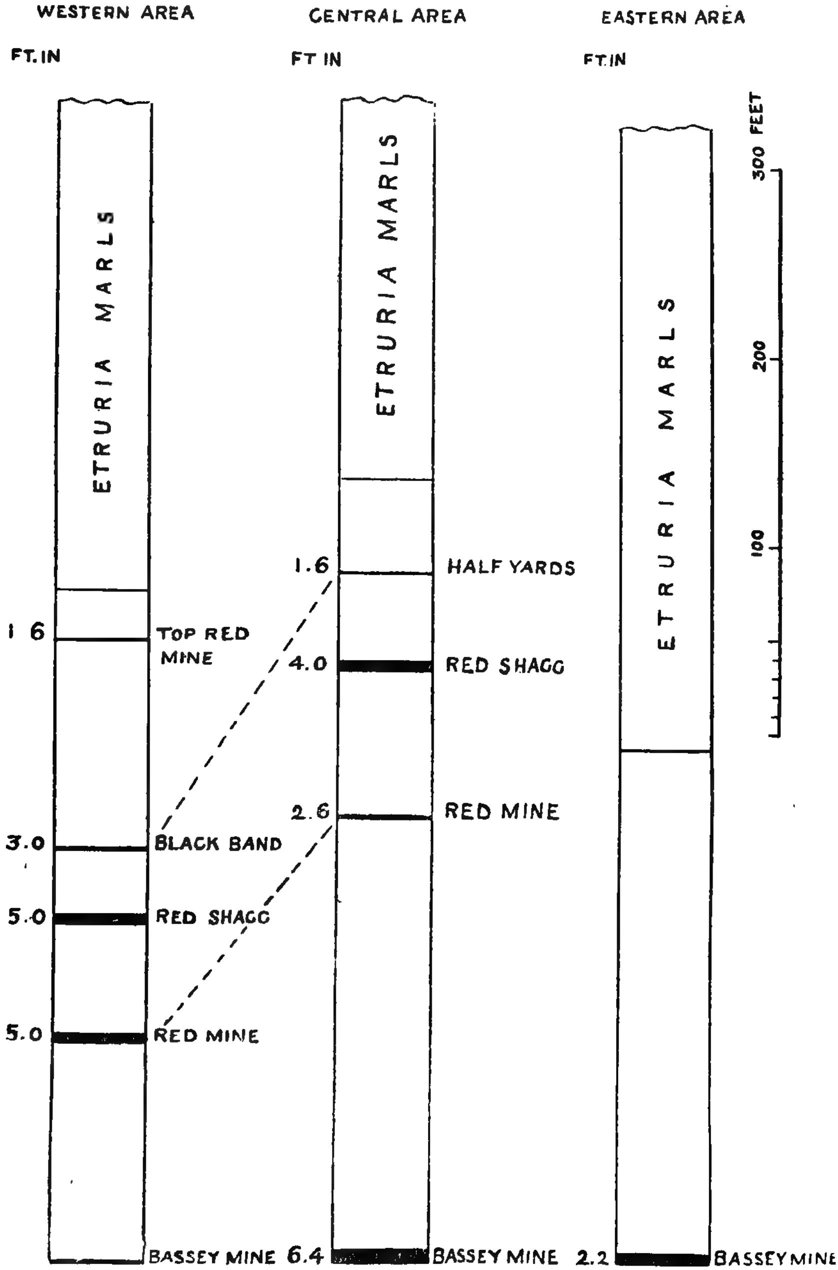
* C. J. Homer, "*Proc. Iron and Steel Inst.*" (1875.)
† W. W. Smyth, "Iron Ores of Great Britain," Part iv., *Mem. Geol. Survey.* (1862.)

Blackband Ironstones.

The Pottery Coalfield stands before any other of the Midland Coalfields in possessing several thick beds of rich ironstone, possessing the character of *blackband,* whose distinguishing

FIG. 19.

COMPARATIVE SECTIONS OF SEAMS OF THE BLACKBAND IRONSTONES.



features are that they contain a high percentage of carbonaceous matter, so that they can be economically calcined, though owing to their somewhat refractory nature they are usually mixed with the clay-band ironstones, and with ore from Northamptonshire.

The working of these ores is mentioned by Dr. Plot, but the clay-bands appear to have attracted chief attention, and for a long period the "black-bands" seem to have escaped notice, for Sir W. W. Smyth mentions the fact that in 1862 they had only within a recent period come into use.

The different bands are usually laminated ores striped with black and brown layers, and containing countless numbers of *Anthracomya Phillipsi* and *Carbonia*. They vary in thickness, from a foot up to as much as 14 feet, but are very irregular in distribution, and in the southern portion of the field the four chief bands recognisable in the central area are reduced to one. Each bed is underlaid by a coal, which appears to vary in thickness in inverse proportion to that of the overlying ironstone As shown in Fig. 19, p. 219, they occur throughout the Blackband sub-division; while at Chesterton a thin bed of low grade is met with high up in the Etruria Marls. At Ridgehill the limestone at the base of the Newcastle-under-Lyme Group is in part replaced by ironstone. This suggests the probability that the "Blackbands" represent a previously existing calcareous rock, in which the lime has been replaced by iron, as demonstrated by Mr. Sorby in the case of the Cleveland ores.

Within the outcrop of the Blackband Group the ironstones have been largely extracted, especially the Bassey Mine, between Shelton and Golden Hill. Shafts reaching the ironstones within the outcrop of the Etruria Marls include Florence, Great Fenton, Racecourse, Brownhills, Grange, Chatterley, Parkhouse, High Carr, Rosemary Hill, Hem Heath, Minnie, and Milbank; but a large proportion of the ore remains untouched, including all within the outcrop of the Etruria Marls south of the Hollywood Fault, and between the Apedale and Newcastle faults, south of Newcastle; while within the outcrops of the Newcastle-under-Lyme and Keele sub-divisions all is virgin ground. The map (p. 15) attempts to indicate the approximate depths to the Bassey Mine over these unexplored areas, and shows a great future for this district, though the inconstancy of development of the ironstones should be kept in mind.

Bassey Mine Ironstone.—Not so uniform as the other bands, but with a higher percentage of carbonaceous matter. The thickness varies from 1½–5 feet, yielding, at Longton, as much as 5,000 tons per acre. It is usually an even bed with numerous lines of deposition, some of the laminæ being almost exclusively composed of the crushed valves of *Anthracomya Phillipsi*, and crowded throughout with *Carbonia*. The underlying coal, averaging two feet in thickness, is suitable for steam purposes. The ironstone occurs throughout the eastern area, but at Great Fenton it is said to possess the characters of the "Shaggs," in

addition to its own properties. In the western area it is feebly developed, and is usually termed the Pottery Bassey Mine, to distinguish it from the Bassey Mine, which is sometimes applied to the Red Mine of Apedale. The persistence of the bed of limestone from 30 to 40 feet above the ironstone which has been mentioned before (p. 118), can certainly be relied upon to indicate the position of the ironstone, in borings and new sinkings (see record of Newstead Boring. Sect. No. 1 Appendix). It should, however, be borne in mind that there are other similar looking limestones higher in the sequence, which might be mistaken for it. The character of the ironstone is shewn by the following sections.

SECTION OF BASSEY MINE IRONSTONE GRANGE COLLIERY, COBRIDGE.

(From Mr. J. H. Cole).

	Ft.	In.
Ironstone	1	6
COAL -	1	3
Ironstone - -	4	10
COAL - -	0	5

SECTION OF BASSEY MINE IRONSTONE, NORTON AREA.

(From Mr. A. R. Sawyer, "Accidents in Mines").

	Ft.	In.
Bass - -	0	9
Ironstone (lean) - - -	1	1
Bass - - - -	0	9
Ironstone -	1	4
Bass - - -	1	0
Ironstone - 8 in. to	3	7
COAL - - 9 in. to	1	6
Shale	1	6

SECTION OF BASSEY MINE IRONSTONE, KIDSGROVE AREA.

(From Mr. A. R. Sawyer, "Accidents in Mines").

	Ft.	In.
Bass -	0	6
Ironstone, Tops -		
Ironstone, Peel (lean)	1	6
CANNEL - -	0	4
Brazils	0	8
Dirt	0	3
COAL - - -	0	6
Dirt	0	10
COAL 12 in. to	1	6

Red Mine Ironstone.—Varies in thickness from 1 foot to 14 feet; in the latter case it is split up by a six-inch seam of coal towards the middle. The bottom stone is the best. An oil shale, yielding 28 gallons per ton, sometimes overlies the seam; above this come the "Flannels," a laminated stone, crowded with *Anthracomya Phillipsi*, underlying a soft sandstone. The underlying coal is only of moderate quality.

SECTION OF REDMINE IRONSTONE, SILVERDALE.

(From Mr. J. C. Cadman*).

		Ft.	In.
Argillaceous sandstone	2 ft. to	30	0
Shales	nil to	3	6
Isaacs (Inferior Ironstone)		0	3
Flannels		0	4
Ironstone		0	4
Flannels		0	3
Ironstone, Tops		2	0
„ Middles	1 ft. to	1	6
„ Bottoms	nil to	3	0
COAL	1 ft. to	1	6

REDMINE IRONSTONE, NORTON AREA.

(From Mr. A. R. Sawyer, Op. cit.)

		Ft.	In.
Argillaceous sandstone	15 in. to	1	6
Marl	nil to	4	0
Isaacs		0	4
Flannels	4 in. to	0	6
Ironstone, Tops		1	0
Oil Shale		0	9
Ironstone, Bottoms	10 in. to	2	0
COAL	20 in. to	2	0

REDMINE IRONSTONE, KIDSGROVE AREA.

(From Mr. A. R. Sawyer, Op. cit.)

		Ft.	In.
COAL		1	0
Argillaceous sandstone			
Marl with lean stone		0	3
Flannels		0	6
Grates (Jacobs and Isaacs)		1	0
Oil Shale and lean Ironstone		0	10
Ironstone	nil to	4	10
COAL	12 in. to	1	6

Red Shagg Ironstone.—Varies in thickness from 9 inches to 7 feet. It is more or less laminated, the layers containing a few valves of *Anthracomya Phillipsi* and numerous large specimens of *Stigmaria*. The seam is overlaid by lean ironstone (grates); often in two bands called "red and black grates." The underlying coal from 1 to 2½ feet thick is of rather inferior quality. The cannel bass is stated by Mr. Homer to have yielded 15 gallons of heavy oil to the ton.

RED SHAGG IRONSTONE, SILVERDALE.

(From Mr. J. C. Cadman, op. cit.)

		Ft.	In.
Grits	nil to	0	9
Clod	2 ft. to	3	0
Red and Black Grates	6 in. to	1	6
Ironstone	1½ ft. to	5	0
COAL	14 in. to	1	8
Fireclay			

* *Trans. Inst. Min. Eng.*, vol. xxii., pt. 1—1901, pp. 96–99.

RED SHAGG IRONSTONE, NORTON.

(From Mr. A. R. Sawyer, op. cit.)

		Ft.	In.
Cossil, lean		0	6
Bass	7 in. to	1	2
CANNEL BASS	nil to	0	6
Ironstone	14 ins. to	6	0
COAL		2	0
Fireclay			

RED SHAGG IRONSTONE, KIDSGROVE.

(From Mr. A. R. Sawyer, op. cit.)

		Ft.	In.
COAL		2	0
Clod	2 ft. to	3	0
Grates	3 ins. to	0	6
Ironstone (Tops)		1	8
„ (Bottoms)	14 ins. to	4	6
COAL		1	6
Fireclay			

Half Yard or Blackband Ironstone.—Varies in thickness from 9 inches to 6 feet, and also considerably in composition. The underlying coal is a moderately good steam coal from 1 to 2½ feet thick.

HALF YARD IRONSTONE, SILVERDALE.

(From Mr. J. C. Cadman, op. cit.)

		Ft.	In.
Loose shale		1	0
Strong black bass	1 ft. to	1	4
COAL AND CANNEL	nil to	0	9
Ironstone	1 ft. to	3	0
COAL		1	6
Warrant		0	4
COAL		0	6
Alum shale			

HALF YARD IRONSTONE, NORTON.

(From Mr. A. R. Sawyer, op. cit.)

		Ft.	In.
Shale			
Bass		0	6
Boring band		0	4
Bass		1	3
Ironstone	1 ft. to	1	2
COAL		1	8
Alum shale			

HALF YARD IRONSTONE, KIDSGROVE.

(From Mr. A. R. Sawyer, op. cit.)

		Ft.	In.
Black bass, containing oil		2	3
Ironstone (Tops)	6 in. to	0	10
„ (Bottoms)	nil to	6	0
COAL	4 in. to	2	0
Alum shale	1 ft. to	1	6

ANALYSES OF BLACKBAND IRONSTONES.

J. Cadman, *Trans. Inst. Min. Eng.*, vol. xxii., pt. 1, p. 99, 1901.

LOCALITY.	SILVERDALE.				LONGTON.
Name of Seam.	Half-yard.	Red Shagg.	Red Mine. Middle.	Red Mine. Bottoms	Bassey Mine.
Condition	Raw.	Raw.	Raw.	Raw.	Raw.
Loss on ignition	46·05	43·45	46·59	39·27	41·56
Ferrous oxide	41·87	42·95	39·70	39·89	45·53
Ferric oxide	2·65	3·29	2·41	15·40	5·00
Silica -	2·20	2·00	4·07	0·51	
Alumina - -	1·45	1·20	0·51	1·00	0·32
Oxide of Manganese -	1·70	2·50	1·10	1·26	1·74
Lime -	3·00	2·34	3·02	2·24	2·91
Magnesia - -	1·08	1·34	2·41	1·01	2·13
Phosphoric acid -	0·61	0·51	0·60	0·54	0·86
Sulphuric acid -	trace	0·28	—	nil.	0·08
Metallic iron - -	34·42	35·17	32·56	41·80	39·13

Pottery Clays, Brick Clays and Marls.—The Staffordshire Potteries afford the great mass of earthenware manufactured in this country, and therefore the raw material on which this trade depends demands some mention.

The early history of the manufacture of pottery in this district is somewhat difficult to trace. The Romans are supposed to have made use of the local clays, but this is not supported by positive evidence. Coarse ware appears to have been manufactured in the district certainly as early as the year 1500, if not, indeed, earlier. Among the productions of the district that of *Butter Pots* appears to have been undertaken at an early date, attaining sufficient importance in 1661 to attract the attention of Government, an Act being passed compelling the potters of Burslem to make their pots of such a size as to hold 14 lbs. of butter, and so hard as not to imbibe moisture by which the butter might appear of greater weight than was actually sold.* In the seventeenth century Dr. Plot, in his *History of Staffordshire*,

* These statements are excerpted from the Handbook to the Collection of British Pottery and Porcelain in the Museum of Practical Geology, 1893,

published in 1686, makes it evident that the local clays used belonged to the Coal-measures. Around Burslem he mentions that "they have as many different sorts of *clay*, which they dig round about the *towne*, all within half a mile's distance, the best being found nearest the *coale*, and are distinguish't by their *colours* and *uses* as followeth :—*

"1. *Bottle clay*, of a bright whitish streaked yellow colour.

"2. *Hard fireclay*, of a duller whitish colour, and fuller intersperst with a dark yellow, which they use for their *black wares*, being mix't with the

"3. *Red blending clay*, which is of a dirty red colour.

"4. *White clay*, so called, it seems, though of a bluish colour, and used for making yellow-coloured *ware*, because yellow is the *lightest* colour they make any *ware* of."

The use of local clays in the manufacture of pottery of a superior kind was introduced by the brothers Ehlers after the Revolution of 1688. They are said to have made use of an ochreous clay occurring at Bradwell Wood, which produced a red ware similar to that of Japan, and in addition manufactured a black body from a mixture of clay and ironstone. Then followed the introduction of Bideford pipeclay, and in 1720 a great improvement was effected by the use of pounded flint as a constituent of the body of the earthenware. But undoubtedly the greatest impetus to the industry was supplied by Josiah Wedgwood, whose beautiful wares drew world-wide attention to the district. Josiah Wedgwood died in January, 1795, at Etruria, the name he had himself given to this part of the Potteries, where he resided. A considerable advance in the manufactures of the district arose from the introduction of Cornish china clay in 1777. Felspar was first employed by Mr. Josiah Spode towards the end of the seventeenth century, who is also credited with the introduction of the use of calcined bones. Hard porcelain was first manufactured in 1850 by Mr. Minton.

The above brief outline of the history of the rise of the pottery industry in North Staffordshire shows that it originated in the district producing a variety of clays, but it has maintained its location here from the accessibility of the seams of coal and the consequent cheapness of fuel, so that though the materials now employed for the earthenware and porcelain are derived from other localities, yet its supply of coal and of refractory clays for fireclays and "saggars" still make it the chief centre of the ceramic manufacture. These clays are obtained from the Blackband Group (Sections of Marl Pits, Nos. 38–54, Appendix), while the chief pottery coals are contained in the measures below, many of them only a few yards below the Bassey Mine Coal.

* Plot, History of Staffordshire, p. 122.

At the Gillow Heath Pottery the marls just above the Silver Mine and Bee Mine coals (p. 82) are used for manufacturing brown pottery, while the fireclay underlying the Bee Mine furnishes the saggars.

The white marl below the Bowling Alley Coal in the neighbourhood of Hall o' Lea is said to be a good marl for the manufacture of jugs, teapots, etc.

Marls.—Besides being directly utilized in the pottery trade the light coloured marls of the Blackband Greup are also used for drainpipes and bricks. Occasionally, as at Queens Street (see p. 71), Scotia and Sneyd Green Marl Pit (see p. 72) and Dukes Bank Marl Pit, the grey marls of the chief coal bearing group are excavated for bricks and saggars; while the grey clays and marls immediately underlying the Blackband Group are universally in request. The most constant source of annoyance consists in the presence of siderite of iron, either in minute particles scattered through the matrix or else aggregated into nodules or bands, rendering the material readily fusible. In the former case the whole mass may be rendered worthless; in the latter the ironstone materials have to be sorted out.

The Etruria Marls furnish an unlimited supply of clay for the manufacture of drain pipes, bricks, and quarries (flooring tiles), so that pits in them extend along nearly their entire outcrop. The clay is also used in the manufacture of superior tiles. Spherules or small nodules of siderate spoil considerable masses, but where the bulk of material is so large the bands containing the injurious mineral can always be neglected. The marl pits are situated at several horizons in the marls. Thus those at Grange lie near the base, those at the Canal Tileries and Peakes near the middle, but the horizon chiefly selected is that immediately underlying the Newcastle-under-Lyme subdivision, along the outcrop of which an almost continuous line of marl pits extends from Etruria to Chesterton.

The Red marls of the Keele Group have not been tried, though in appearance they are identical with, and belong to the same horizon as the red marls used near Wrexham for terra-cotta ware. The chief drawback consists in these marls being interstratified with beds of sandstone of little value which would therefore form large quantities of quarry waste. The thickest beds of red Keele Marl we know of are those cut through by the North Staffordshire Railway at Keele Park Railway Station (Section No. 62, Appendix III.) and those in the Trentham boring (Sect. No. I, Appendix III.).

The red marls of the Keuper are chiefly in use in the southeast around Blythe Bridge for bricks and coarse drain pipes, but are inferior to those made out of Coal-measure clays and shales.

In the western area the boulder clays of the Drift are called upon to furnish bricks for local use, the most extensive pits

being those in the neighbourhood of Crewe, where the modern development of the town demands a constant supply of new bricks. Boulder-clay has also been much used for "marling" the soil, but this practice has disappeared with the introduction of artificial manures. The evidence of this old custom is to be found in the numerous ponds scattered over the clay areas, though many of these have been dug for drinking troughs for the cattle.

Building Stones, Road Metal and Limestone.—The poverty of the district in local building stone is shown by the majority of the dwelling houses being constructed of brick and not of sandstone, as in the Yorkshire or South Wales coalfields, where the Coal-measure sandstones furnish abundant building materials. Where stone has been used in the more important buildings of the Potteries, it has been imported. Except the red sandstones of the Keele Group, the Coal-measure sandstones and grits are not of sufficient hardness to furnish building stones. The beautiful mansion of Keele Hall forms a striking exception. This is entirely built out of the Keele sandstone obtained on the estate, and shows that with proper care taken in selecting the stone the sandstones of this sub-division, as in other areas in the Midlands, yield a good weathering stone of a pleasing colour.

As might be expected, the harder grits of the Millstone Grits furnish the chief stone for buildings or other constructions. The outcrop of these grits on the eastern side of the coalfield and along Mowcop is, therefore, marked by large quarries. Besides being used locally for cottages, farmhouses, and walls, it is also carted into the Potteries. When first taken out the stone is fairly hard and open textured, but subsequently sets hard and retains its sharp edge. Mr. Barrow suggests that this is caused by the felspar in the grit, which, as it slowly decomposes, sets free soluble silica, and so long as the stone remains underground, and is kept damp the silica remains in a soluble state; but when built into a house or placed in a position where the silica can dry, it assumes the insoluble state, and holds the grains of the rock together with great tenacity. If, therefore, the amount of soluble silica present, in a specimen taken fresh from the quarry, be tested, a ready means might be afforded as to whether any particular sandstone will or will not set firmly.

Mr. Peake, of the Gillow Heath Pottery, has lately worked as a whetstone a fine sand-rock lying at a depth of about 110 or 120 yards below the Cannel Row (p. 83), north-west of Gillow Heath.

A better class of building-stone is obtained from the Keuper sandstone, in which extensive quarries have been opened at Beech, Chapel Chorlton, Bearstone, Betton, Caverswall, and Fulford. At Chapel Chorlton the following section gives the character of the beds :—

QUARRY IN KEUPER BUILDING STONES, CHAPEL CHORLTON.

	FT.	IN.
Brown sandstone and thin marls -	10	0
Hard mottled sandstone - - -	3	0
Hard mottled sandstone, mottled at top, white below-	8	0

The white variety was in great request. This does not occur in a distinct bed but graduates upwards into the pink, brown or red kinds. In no instance does the stone approach the quality of the Hollington Keuper sandstone, nor can it be extracted in such large slabs.

For material for first-class roads the district has to look to other areas, the county roads leading to the Potteries being for the most part made from the basalt of the Clee Hills, or the felsites of Pen-maen-mawr. For second-class roads the Crowstones below the Third Grit and the pebbles from the shingle beds of the Bunter furnish abundant material.

The inlier at Astbury affords the only occurrence of Carboniferous Limestone within the district. It is here largely quarried for conversion into lime and cement. Reference must be made to the Mountain Limestone at Cauldon Low and the Weaver Hills. Of exceptional purity this rock is being extensively quarried for lime, for a flux in the Potteries and South Staffordshire Ironworks, and for the Alkali works at Wheelock and Middlewich.

Moulding sand, Potters sand, Sand and Gravel.—The loamy varieties of Bunter sandstone yield locally an excellent moulding sand, and are quarried around Baldwins Gate for use at the Crewe engineering works. It is capricious in its occurrence, passing horizontally and vertically into coarser varieties unfit for moulding. The Drift sands are in much request by brickmakers and potters, considerable quantities being sent into the Potteries from the large pits at Alsager. The Drift also furnishes building sand, and small gravel for paths. In more than one locality in the Biddulph Valley the soft beds of the First Grit are now used for moulding sand.

Vegetation and Soils.—Just as the surface features have largely resulted in North Staffordshire from the structure of the rocks, so the vegetation and soil is found dependent on their composition. Over the coalfield the original vegetation has been largely removed, and it is now a district where buildings and refuse heaps interspersed with pasture land, lie in the midst of a country consisting of moorland on the east, and grazing and pastoral land on the south and west. The hard solid rocks of the Millstone Grit form a large part of the moorland. These rocks weather very slowly and any soil formed is quickly swept off their slopes, while the interstratified shales weathering down into clay form a cold soil, supporting only coarse herbage. On the south the soft sandstones of the Trias give rise to a warm soil; but the pebble beds are more suitable

for forest land, and it will be observed that the chief woods, such as those of Swynnerton, Trentham, Maer and Moddershall, all lie within the outcrop of the Bunter. As in other pebble bed areas, the holly tree flourishes. On the Drift plain to the west, areas occupied by clay are devoted to pasture; in those where sand lies at the surface much corn is grown. This is due to this land entailing less labour in ploughing; the crops also mature earlier, though there is a tendency for them to be seriously affected by even short spells of drought.

Population in its relation to the distribution of the rocks.—One of the most noticeable features in the district is the spread of the Pottery towns along the outcrop of the pottery marls and coals, the towns having gradually extended themselves until they now join from Golden Hill on the north to Longton on the south. These constitute the chief manufacturing centres of North Staffordshire. On the other hand, the largely suburban character of the ancient town of Newcastle-under-Lyme arises from a wide strip of barren measures being let down by the Apedale Fault (p. 165), between the Pottery towns on the east and the mining districts of Silverdale and Apedale on the west. Before the commencement of the comparatively modern trades of pottery and mining the country occupied by the Triassic rocks, from the picturesque character of its scenery, the abundant supply of pure water, and fertility of soil, attracted residents, and we thus find the ancient seats situated within their outcrop; while within recent years there is a growing tendency to choose the neighbouring Triassic areas for the erection of better-class villas. On the Drift plain the position of the villages is governed by the distribution of the sands, partly on account of the character of the soil, but chiefly as the sands are the only local source of a water supply.

Water Supply.—The water supply of the Potteries is obtained from the rocks in the neighbourhood, and will be considered according to the rock formations from which it is drawn.

A considerable amount is collected by the Pottery Waterworks from natural springs issuing from the Millstone Grit at Wall Grange, and from an adit driven across the First and Third Grits near the bottom of the Endon Valley at Stockton Brook (p. 29). In each instance the water is derived from the much-jointed and highly-inclined grits, the shales below acting as an impervious floor. At Knypersley the grits throw out much water, forming a large portion of the head waters of the Trent.

In the Biddulph Valley the chief water supply comes from the Millstone Grit, from which numerous springs issue along the escarpments, especially where intersected by faults. Trent Well is a strong spring, supplying the source of the Trent between Crowborough and Biddulph Moor. It is probably connected with the belt of fracture we have named the Crowborough Fault (p. 174), where the latter crosses the lowest grit.

Another strong spring is that of Corda Well, thrown out by the Third Grit on Congleton Edge south of Cheshire Close. West of Nettle-beds, Biddulph, a well was lately sunk on the dip slope of the First Grit, lying at a depth of 9 feet below the surface. Water was here reached at a depth of 12 feet from the surface. The success attending the adit at Stockton Brook (p. 29) suggests that a similar method would tap a large body of water in the grits on either side of the Biddulph Valley, if an adit were driven in on the dip slope of the grits below the level of the springs in the neighbourhood.

The Coal-measures are not an available source of supply owing to contamination from the coal-mines, though many of the sandstones are porous, and contain much water. In sinking shafts through the Etruria Marls the green grits are a recognised water-bearing stratum throughout the district.

The Triassic rocks must, however, be regarded as the most important source of supply. From springs in the Bunter conglomerate at Wall Grange the Pottery Waterworks obtain 2,000,000 gallons daily. Near Meir Railway Station the same company pump a considerable amount from galleries driven in the Bunter sandstone. The subterranean water contained in the same formation is utilised by the Pottery Waterworks Co. in the boring at Hatton, and by the London and North-Western Railway in the boring near Whitmore Station, which supplies Crewe town and several small villages around. Both these borings are situated in the Meece valley, and are sunk in a shallow trough in the Bunter Sandstones and Conglomerates. The copious supply obtained from the Triassic rocks shows their great porosity, for they are not much jointed, so that the water must be held within the interstices of the rock itself. The water is remarkably free from solid matters, being only 6·10 grains per gallon at Whitmore.* It must be remembered, however, that the water is obtained from within the outcrop of Bunter, except at Meir, where the sinking starts in Keuper Marl, but near its fringe. In other parts of England it frequently happens that when the Bunter rocks are tapped beneath a thick cover of Keuper Marl the water is heavily charged with salts, and is rendered undrinkable. It is by no means unlikely that this will be the case with the water-bearing Triassic rocks lying beneath the wide sheet of marl to the south of the district. Several strong springs flow from the Bunter Sandstones and conglomerates. The lake at Trentham Hall is filled from springs issuing along fault lines in Spring Wood and Knowl Bank. At Moddershall several copious springs burst out from the Bunter at or near its junction with the marly portion of the Keele Group, while a large volume of water is poured out from the same formation into the lake at Maer Hall, from which it issues as the Tern river, to

* "Permian and Triassic Rocks," *Mem. Geol. Survey* (1869), p. 119.

receive additional water from numerous springs flowing from the Bunter in the Willoughbridge valley.

In the western drift-covered area the chief water supply is derived from the Glacial sands. The water is frequently hard, and near villages is liable to contamination. It is also very capricious in its occurrence, and cannot be regarded as a satisfactory source, though it is in much request, owing to the ease with which wells can be sunk through the sand.

Where Boulder-clay overlies the sands the liability to contamination is diminished, unless the clay is only a mere capping.

PART II

THE CHEADLE COAL FIELD.

BY G. BARROW.

CHAPTER XIII.

INTRODUCTION.

The fold enclosing the Shaffalong Coalfield (p. 74) is not of sufficient depth to include more than the lower portion of the productive measures within the encircling Millstone Grit. A further fold over of the strata, accompanied by faulting, introduces eastward the self-contained and isolated coalfield of Cheadle. Unfortunately, owing to the strip of Triassic rocks which extends northward to Hulme from the main spread of Triassic rocks, burying up the Pottery Coalfield on the south-east, we are unable to state other than approximately, what thickness of Coal-measures of the Potteries are present in the Cheadle area; for between it and the Pottery Coalfield there extends a zone of unproved Carboniferous rocks concealed beneath the Trias. Palæontology, at present, is of little use in comparing these isolated areas. Each coalfield may then be taken as a unit, and the correlation of the strata of the two areas may be safely left among many other important problems for future investigation.

The small area occupied by the Cheadle Coalfield is remarkable for the fact that its main features are of two widely different ages. What may be broadly called the northern portion is composed of Carboniferous rocks, forming a sloping tableland essentially of pre-triassic age, modified by later denudation. Upon this older land surface the Triassic rocks were deposited, but except off a small portion of the northern area they have since been denuded; thus restoring the old pre-triassic surface. In the southern area, however, the newer rocks have escaped denudation to a considerable extent, and now form a second and later tableland, overlooking the first and older one. The true form of the older tableland is somewhat obscured by the hill of red sandstone at Cheadle, but from its summit it is seen that this isolated eminence is simply a detached portion of the newer Triassic plateau, and thus really serves to emphasise the fact that the Carboniferous rocks form a pre-triassic tableland.

Physiography.—The highest ground occurs in the northern area, and is formed of Carboniferous rocks, which attain an elevation of 1,000 feet about Ipstones, and 800 feet in the neighbourhood of Wetley Rocks. The Triassic rocks do not attain so great an elevation; at the edge of the plateau overlooking Cheadle the ground maintains a fairly uniform height of 700 feet above sea-level, and the top of the hill at Cheadle is at the same height.

The drainage of the area is effected by the two rivers, the Churnet and the Tean, and their branches. Of these the Churnet, which flows for the most part in a deep valley, often almost a gorge, is the more important; and so regular, on the whole, is the plateau on both sides of the river that it is frequently possible to look across the deep valley without realising its existence. The chief branches of the Churnet are three in number, and flow through the Consall Woods, the valley between Ipstones and Froghall, and the beautiful gorge of Dimmings Dale. The latter is renowned for its steep, craggy, and densely-wooded sides, which are cut in the Triassic rocks, while the other two channels are in Carboniferous rocks. Though less gorge-like than Dimmings Dale they both have, locally, steep sides. The area about Cheadle is drained by a few small streams flowing in shallow hollows, which, uniting to form the Tean, eventually join the Churnet to the south.

General Geological Structure.—There are really two structures in this area, one of which is pre-triassic and affects the Carboniferous rocks only; the other post-triassic, which locally modifies the older structure but mainly affects the Triassic rocks only.

Ignoring the unconformable cover of the latter, the Carboniferous strata lie in what is usually called a basin; but a far more apt simile is that of a large fresh-water mussel shell with the length of the shell lying north and south, and the hinge to the west. On the hinge side are the steep dips, and form the deepest part of the shell, from which the beds rise gradually in all directions. This structure is modified by faults mostly of pre-triassic age, but an important local modification has been produced by two dislocations affecting the Trias in the Draycott area.

The Bunter sandstone was deposited upon the Carboniferous rocks, which were extensively eroded long after this shell form had been established; but in spite of the extreme irregularity of the base in many cases the Bunter is built up of horizontal though lenticular beds. Though this horizontality has been locally destroyed by post-triassic faults, it is, on the whole, fairly well preserved, as is shown by the outcrop of the massed conglomerates or shingle beds, which occur at nearly the same height above sea-level over a large area. The most striking feature of the district is the bold escarpment of the Triassic rocks, which faces Cheadle in horse-shoe form. A subordinate

feature is the outlying hill of Bunter at Cheadle, which shows that this deposit once covered the whole area, and that the escarpment is the result of comparatively recent denudation.

Table of Formations.—The rocks occurring in this area may be divided into four groups in descending order of sequence, as follows:

TABLE OF STRATA.

PLEISTOCENE AND RECENT	Recent or Post-Glacial	Alluvium
	Glacial	Clay with stones.
TRIAS	Keuper	Marl. Flags and building-stones.
	Bunter	Sandstones and conglomerates.
CARBONIFEROUS	Coal-measures	Sandstones, marls, clays, shales and seams of coal.
	Millstone Grit Series.	Grits, Crowstones and shales with occasional thin seams of coal.

The superficial extent of the strata is shown on the one-inch map. (Pl. II. Appendix.)

CHAPTER XIV.

CARBONIFEROUS ROCKS.

The Carboniferous rocks represented within the area consist of a portion of the Coal-measures, and of the underlying Millstone Grit Series. Natural outcrops of the latter, and of the lowest part of the Coal-measures are abundant, and their nature can be accurately ascertained. But the higher rocks are confined to an area where sections are rare or entirely wanting, and we are forced to rely on mining information for most of our knowledge of these beds. Seams of coal occur throughout the Coal-measures, but they vary much in quality and thickness, and in addition are more abundant or closer together at some horizons than at others. It has been found that black shales are abundant in the lower part, and comparatively rare in the upper, while the strong grit bands are confined to the Millstone Grit.

By the aid of these characteristic differences, the Carboniferous rocks may, for convenience of description, be divided into the following five parts, or groups, in descending order:—

5. *The Upper Pale Group.*—The most abundant rock is called grey shale, and contains coal-seams fairly close together. This does not weather as a shale in the sense in which the term is used by geologists, but decomposes into a nearly white clay that becomes almost fluid when wet. Even the sandstones from this part of the series disintegrate on exposure to the air. From the persistent whitish colour of all these rocks when weathered it is both natural and convenient to call the group the pale-series. The Four Foot Coal forms the base.

4. *The Lower Pale Group.*—The same white clay material is here almost as abundant as in the last group, but there is also a little dark shale. The coals are further apart, and the top one alone, the Dilhorne Coal, has been extensively worked. Some dark shale and more coherent sandstones occur in the lower part of the series. The top of the Woodhead Coal forms the base.

3. *The Woodhead Coal and Woodhead Sandstones.*—Both above and below the seam known as the Woodhead Coal is a considerable thickness of dark shale, which distinguishes this horizon from any higher one. The sandstone which underlies the lower band of shale consists of a great number of thin beds all of which are fine in grain and more or less flaggy. About the middle of the mass is a band cemented by carbonate of lime and probably some iron. When undecomposed this is an intensely hard rock and easily recognised.

2. *The Lowest Coal-measures*—The feature of this group are the thick masses of black or dark shales associated with coal-seams and sandy bands, the latter tending to pass into gannister, often of excellent quality. Of the coal-seams, one the Crabtree or Lower Stinking Coal is very persistent, and has been worked to a considerable extent. The others vary greatly in thickness, and are often absent. There seems reason to believe that this group is the equivalent of the Lancashire Gannister Series.

1. *The Millstone Grit Series.*—This is at once recognised over the greater part of the area by the size of the grains composing the body of the grits (the First and Third) as well as by their thickness. They continue to be strong grits to the east and north, but in the Dilhorne area they rapidly deteriorate until they are scarcely recognisable. A mass of black shale similar to that in the group above separates the two grits, and there is a seam of coal always present above the Third Grit; it varies, however, from little more than a smut to a good seam 2 feet 10 inches thick. Below the grit there is a mass of dark shale associated with red marls and sandy bands of a very variable nature.

There is a considerable variation in the thickness of these five groups as we pass from one area to another, so that it is not possible to say what is the exact thickness at any one spot. In the course of mining operations all but a small portion of these rocks has been proved in shafts or borings, and by adding these together we find the total thickness of the true Coal-measures in the Cheadle area to be about 1,600 feet, while the Millstone Grit Series has been proved to a depth of about 450 feet.

On comparing the thicknesses of the four upper groups with the Coal-measures on the eastern side of the Pottery Coal-field (Fig. 2, Plate I) we find that the highest beds of the Cheadle Coal field do not extend much higher than the Bambury coals. We, however, know nothing of the laws governing the thickness of the measures between the Potteries and Cheadle, and though it is probable it is not absolutely certain that the two areas were ever in direct continuity. If movement were in progress during the deposition of the strata it may well be that beds present in one area are absent in the other, and vice-versâ. Any satisfactory correlation of the two areas must be based on a closer palæontological investigation than has at present been attempted. To be conclusive this must be exhaustive, which, as yet, is far from being the case.

THE MILLSTONE GRIT AND ASSOCIATED SHALES.

These rocks form a ring round the greater part of the Cheadle Coalfield, but the southern and south-western portion is buried under the Triassic rocks, and its exact position cannot be fixed; while the symmetry and continuity of the ring are

greatly broken by faults, which for short distances make the outcrops of the different beds somewhat difficult to trace; but over the greater part of the area these beds have such well-defined characters that even small outcrops can usually be recognised.

The series can be best studied in the Froghall and Ipstones areas, where the rocks differ least from the well-known types further north, such as at the Roaches. Shafts and borings in search of ironstone have proved the thickness of much of the sequence. A borehole close to Abovechurch, north-west of Ipstones, passed through the total thickness of the Third Grit, and pierced about 100 feet of the underlying rocks. Trials were also made in the Oakamoor area in the beds below the Third Grit, which proved a seam of coal some 10 inches thick, at a depth of about 95 feet below the grit. Other borings have penetrated still lower beds, but it is not possible to exactly fix the horizon at which these started. The following section shows the approximate thickness of the grits and shales in the Ipstones and Churnet Valley areas, in descending order:—

	ft.	in.
First Grit, about -	100	0
Dark shales with a little sandy marl in upper part	120	0
Third Grit - - -	140	0
Marls, thin sandstones and black shales, about 200 feet proved - -		

Beds below the Third Grit.—The dark shales which lie below the Third Grit are exposed in the cutting on the Caldon Low Tramway, and still lower beds are seen in the stream (Shirley Brook) that flows south towards the tramway in the neighbourhood of Foxt. At the point where this stream turns abruptly west a small brook joins it from the east, and in the low scar at their junction a curious small coal seam occurs, about 10 inches thick, apparently at the same horizon as that often met with in the borings about Oakamoor. The seam at Shirley Brook appears to be highly bituminous and pyritous, and is crowded with *Goniatites*. A little north of this point an interesting bed of sandstone crops out and can be followed for a considerable distance in the sides of the stream. At first it contains a few small pebbles in its upper portion, but further north these increase both in number and size till the rock resembles the Third Grit. Though thin it is very hard, and after rising from the sides of the hollow it occupies a large area about Lanehead. This bed is met with again at the smithy north-east of Foxt, where its presence is due to a fault. It is here more like the Third Grit in appearance, but a shaft proved it to be only some thirty feet thick. This tendency of the sandy beds in this district to become thicker, coarser and more pebbly is not confined to this rock; for the examination of part of the Ipstones area made it clear that a number of thin pebbly grit bands come on, and partly replace the masses of shale so conspicuous in the Endon area.

On the opposite side of Cheadle, however, the reverse phenomenon is seen. There the beds below the Third Grit are mainly soft shales associated with thin crowstones, good examples of which may be seen to the west of Banktop Farm.

The Third Grit.—Generally speaking, this grit is coarser and thicker than the First. There is no need to give a detailed description of the outcrop of this rock for it runs parallel to the First Grit, and its position may be defined as being invariably a little further off from Cheadle than the latter. In the Ipstones and Oakamoor area it is about 140 feet thick, and the thickness changes slowly and apparently evenly in definite directions. It has gradually thinned away from 190 feet in the Stocton Brook area; but the evidence shows clearly that these grits do not vary in thickness in comparatively short distances, as is often supposed. They are really built up of a considerable number of lenticular beds of grit, which often die away in a short distance. But the total thickness of grit built up of these lenticles varies very little over considerable areas, as the numerous shafts and borings show. The best outcrops occur as crags about the Caldon Low Tramway, near Abovechurch (Ipstones area), and the Belmont gorge to the east of the Churnet. On the west side of the Churnet the most northerly outcrop near Park House is obscured by Drift. About Consall, however, it makes a bold feature, but begins to thin away to the south. It is still recognisable at Bank Top Farm, but at Stansmore Hall, north-west of Dilhorne, the rock is recognised more from its position above the thin hard sandstones (crowstones) near Stansmore Wood than from its own characters. Its outcrop further south is covered by the Bunter.

An excellent series of sections of the beds associated with the Third Grit occurs in the little valley—in places a gorge—to the east of Booth Farm, rather more than a mile north-north-west of Froghall. In the eastern branch of this valley a small adit has been driven for a short distance immediately below a hard shale band that lies about half-way between the two grits. The section in descending order is as follows:—

Dark shales.
Dark hard shale band, about 1 foot.
Impure coal, a few inches.
Calcareous ironstone, a few inches.
Dark shales.

The hard shale band has been recognised at several localities, and though it does not here contain *Goniatites* there can be little doubt it is at the same horizon as the band full of *Goniatites* near the Knypersley Reservoir (p. 307). It must not, however, be confounded with a band with *Goniatites* above a coal lower down in this mass of dark shale.

This lower band occurs immediately above the Third Grit Coal, and fragments of it are seen in every tip-heap from the old coal

workings to the west and north of Ipstones Church. The coal has been extensively mined in this neighbourhood, and one shaft is still being worked, the coal being 2 feet 10 inches thick and of fairly good quality. About half a mile west of the church a borehole, known as the Abovechurch Bore hole, was put down to see if any workable ironstone was present. A seam was found, but its poor quality did not encourage a continuation of the enterprise. The exact position of the Third Grit Coal is shown by the following account of the boring:—

THE ABOVECHURCH BOREHOLE.

	ft.	in.
Soil and clay	9	0
Black shale. Goniatite shale band at base	22	0
COAL. The Roaches Seam	2	10
Fireclay	8	0
Sandstone rock. Third Grit	144	0
Hard marl	9	0
Red and brown rock	7	0
Roach or gritty shale	33	0
Grey shale	36	0
Black shale	27	0
Grey shale with red bands	1	6
Black shale with red bands	1	0
Red hydrate (ironstone), said to be	1	5

Three shafts were sunk through the lower portion of the shales to this coal. One, three-quarters of a mile south-west of Ipstones; a second (New House) a little south of Ipstones; and a third half a mile south-east of the village.

These shafts appear to have been made under the impression that these dark shales were at the same horizon as those above the Froghall Ironstone, which they closely resemble. They proved a curious fact; in all cases the coal has passed to a mixture of coal and ironstone, closely resembling the one in the gorge near Booth Farm referred to above. In this particular area this curious admixture occurs at three distinct horizons, for it is also met with in the Froghall Ironstone.

In the small valley, rather more than a mile due north of Foxt and close to the fault shown on the map, the Third Grit Coal is exposed, and has been worked. About the Lees, west of Whiston, the coal has again been worked; the goniatite shale is everywhere seen in the spoil heaps, and fragments of impure ironstone show that the mixed material also occurs in this neighbourhood. To the north-east of Whiston no old workings have been found, but as we approach Oakamoor the coal has been extensively mined, and many old pits are still open in this neighbourhood. A considerable portion of the outcrop of the shales above this coal is cut out by a fault running along the foot of the escarpment of the First Grit. The tunnel at Oakamoor passes through the greater part of these beds, and a great quantity of the *Goniatite* shale may still be seen in the spoil heap at the west end of the tunnel.

Close to the Churnet on the northern edge of the First Grit a shaft was sunk to the Third Grit Coal, and some of the overlying shales are exposed in the banks. To the west and south-west, however, nothing is seen of these beds till we reach the ground between the outcrop of the two grits to the south of Consall village. This ground is intersected by small gorges, which give an almost complete section of these shales. In the wooded ravine—shown on the map—the hard shale band about the middle of this series is particularly well seen. It is 4 feet thick with a coal smut below, but no fossils were found.

Owing to the faulted nature of the ground these shales are difficult to trace for some distance to the south, and the only good exposure of them occurs in the old marl pit close to Bank Top, about a mile north-north-west of Foxfield Colliery. A hard calcareous band associated with some traces of coaly matter seems to be the only representative of the Third Grit Coal, but the pit is too old for the section to be clearly understood. That there is no good coal here seems clear, for it would otherwise have been worked, as there is no other easily accessible coal in this neighbourhood; moreover there are numerous openings for marl or shale to spread on the dry Bunter sandstone soil, and some of them must have cut open the coal if it existed. A little south of this area these shales are faulted down by the Dilhorne Fault and covered by the Bunter sandstone.

The First Grit.—This is a moderately fine-grained rock, rarely containing pebbles; it has a local tendency to weather red which imparts a distinct colour to the soil. This rock occurs more often than is usually supposed on the east side of the Churnet, owing to repetition by faulting. Commencing at the north-east end of this area the First Grit is exposed in the little stream in Coalpit Wood, about a mile west of Belmont Hall, which stands on the same rock repeated by a fault. The fine crags at the south end of the hill, evidently close to the fault-face, enable the bed to be examined here. It is again brought up by a fault, and forms the hill of Noonsum Common; while another fault repeats the grit which forms the hills to the south on which Booth and Hermitage farms stand. A large fault throws the grit down beneath the Ipstones and Froghall Valley, and it does not crop out again till we reach the high ground east of the village of Ipstones. The village itself stands on grit, but it is not easy to say if this is the First or Third. The cause of this difficulty is the doubtful position of the large fault just referred to. If this passes on the west side of the village, then the south end of the latter is on the First, and the north end on the Third; if, however, the fault passes on the east side, the reverse is the case, for the mapping makes it clear there are two different grits here. The church undoubtedly stands on the First Grit. To the east of the Ipstones Valley another fault throws up the First Grit, which forms the small round

outlier to the north of Foxt. Part of the hill on which Foxt stands is also formed of this bed, but the village may stand on the Third Grit, if the fault so clearly seen passing close to the inn further north passes on the west side of Foxt; if it passes on the east side of the village the latter is on the First Grit. It was not found possible to settle this point owing to insufficient evidence.

The First Grit covers a large area in the neighbourhood of Whiston, and the base of it is seen in the old reservoir at the abandoned copper works. There is a gradual passage here from the grit to the underlying shales. This prevents the rock making the usual bold feature, the base being at times by no means easy to follow. As we approach Oakamoor, shafts have been sunk through the grit to reach the underlying coal, from which we gather that the grit must be about 90 to 100 feet thick. In the wood on the north side of the Churnet, opposite the western end of the tunnel, the grit makes an unusually bold escarpment. For a short distance on the south side of the river a similar escarpment occurs; it is, however, abruptly truncated by a fault just before these rocks are covered by the Bunter sandstone.

Returning to the northern area, near the Churnet, the grit has a double outcrop for some distance to the west due to a fault, but its exact position is difficult to fix, as the hollow in which it occurs is covered with downwash. The large fault passing near Consall New Hall throws the grit up again, so that it crops out in the sides of the valley and near the Hall Farm. On the west bank of the Churnet a large quarry has been opened in this rock, which here forms an excellent building-stone.

A large fault trending north-west repeats both these outcrops, as the map clearly shows. The shorter and more southerly outcrop is well seen in the side of the small stream in the Consall woods, and by its position and mode of ending clearly shows the course of two of the faults. The more northerly outcrop is particularly clear about the sides of the stream which cuts right through this rock, and gives an excellent section of it. As we leave the stream, and approach the faults shown on the map further west, the position of the bed is more difficult to fix. Close to the Wetley Rocks road the First Grit is faulted against the Third, so as to make the whole appear a continuous outcrop of one grit. Further south the First Grit is very difficult to trace continuously, partly owing to faults, and partly to the fact that both the First and Third Grits begin to thin away rapidly in this direction. The bed of sandstone to the east of Hilltop Farm is probably this rock, as is also the sandstone exposed in the Foxfield Railway, a little south-east of Stansmore Hall. The great east-and-west fault at Dilhorne throws down the whole of the Millstone Grit Series, and their further course west of the Cheadle basin is covered by Triassic rocks. The greater part of the rock between the First and Third Grits consists of dark shale. Close under the First Grit, however, the beds vary

somewhat, being often lighter in colour, and of a more sandy nature. Occasionally a thin band of sandstone occurs, but it is distinctly rare and impersistent. Owing to the occurrence of these soft shaly beds between two much harder rocks, they are rarely seen except in stream sections or artificial openings.

THE COAL-MEASURES

Between the Millstone Grit and the succeeding Coal-measures a perfect conformity exists. The same lithological distinction between the two members as holds in the Pottery Coalfield can be readily observed in that of Cheadle. In both cases, coarse grits absent in the Coal-measures, distinguish the inferior group, the First Grit being practically the last coarse arenaceous bed of the Carboniferous sequence, those met with in the Coal-measures all being of a sandstone character.

The palæontological evidence for classing the lowest beds ot the Cheadle Coal-measures with the strata immediately succeeding the First Grit in the Pottery Coalfield is also very conclusive. Thus in both areas a seam of coal, known as the Crabtree Coal, is in each associated with an abundant marine fauna consisting of *Gastrioceras* (*Goniatites*) *Listeri* and *Pterinopecten* (*Aviculopecten*) *papyraceus.*

The coal seams of the succeeding groups (3–1), however, receive names which do not in any way recall the seams of the Pottery Coalfield. These seams are distributed through the sub-divisions, into which we have arbitrarily separated one portion of the Cheadle Coal-measure sequence from another, in the following order:—

SECTION SHOWING COAL SEAMS IN THE CHEADLE AREA.

			ft.	in.
UPPER PALE GROUP.	1	COAL AND SMUT	2	6
		Measures	42	0
		TWO-YARD COAL	5	6
		Measures	76	0
		HALF YARD COAL	2	6
		Measures	61	0
		YARD COAL	3	6
		Measures	51	0
		LITLEY COAL	2	9
		Measures	33	0
		FOUR FOOT COAL	3	6

			ft.	in.
Lower Pale Group.	2	Measures about - -	120	0
		COAL (VARIABLE) - - - - -	2	0
		Measures - - - -	60	0
		DILHORNE COAL- - - -	6	0
		Measures - - -	190	0
		STINKING OR ALECS COAL	3	9
		Measures -	55	0
		FOXFIELD COAL -	1	8
		Measures - - - -	64	0
		Coal 7 in. (Black Seat 2 ft. 6 in.), Coal 8 in., below	1	5
		Measures -	130	0
		COBBLE COAL	1	3
		Measures - - -	55	0
		COAL (NO NAME)- -	1	1
		Measures	95	0
		RIDER COAL -	1	6
		Measures -	125	0
Woodhead Measures.	3	WOODHEAD COAL	2	9
		Measures	500	0
Lowest Coal-Measures.	4	STINKING OR CRABTREE COAL	2	0
		Measures - -	120	0

FIRST GRIT.

Lowest Coal-measures (*Crabtree Coal and Associated Rocks*).

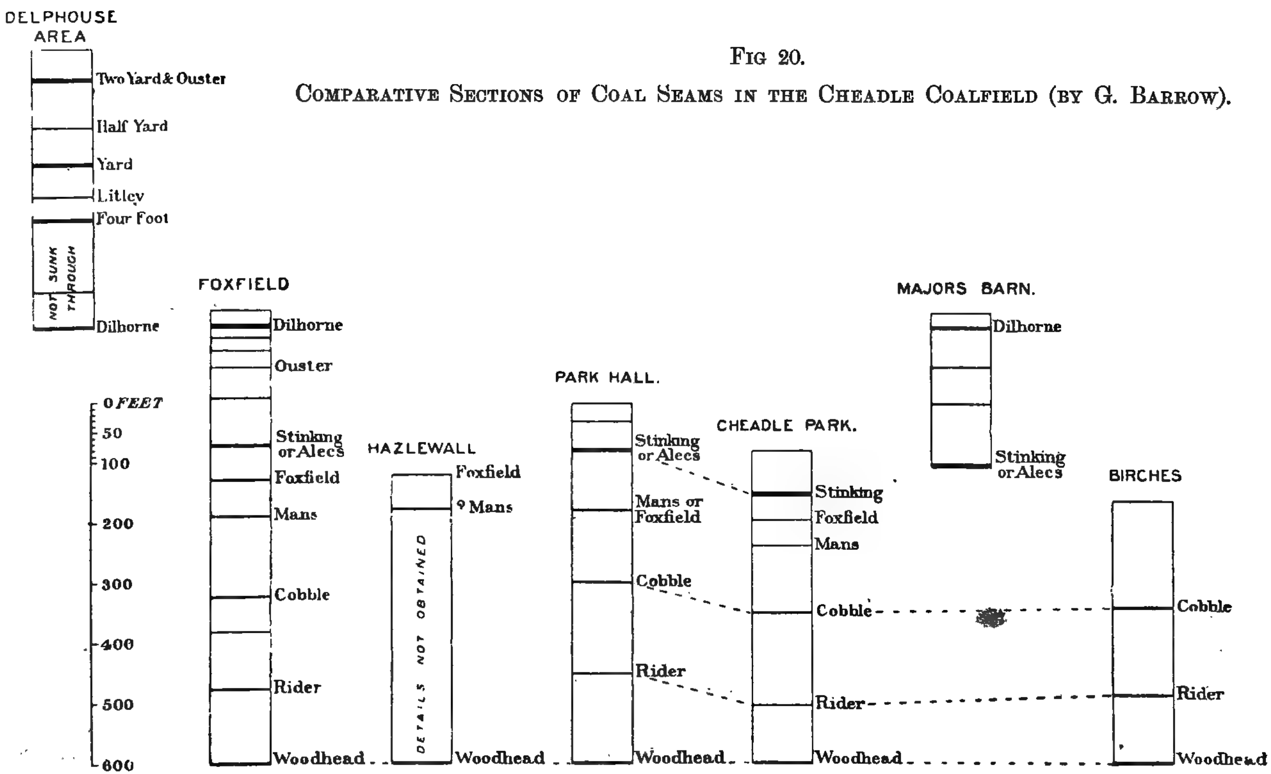
This group consists essentially of dark shales separated by bands of fireclay and sandstone or gannister. The whole thickness of the group was pierced in the boring from the bottom of the pit at Park Hall Colliery,* but there is reason to believe the beds here are somewhat thinner than in the Froghall and Ipstones area. The section shows that several small seams of coal are present, but only one, the Crabtree or Stinking Coal, is of any thickness. The sandy bands in this series are liable to much greater variation than the dark shales, a phenomenon especially well shown by the bed beneath the Crabtree Coal, which may either be a pebbly grit, a series of thin fine sandstones, or a gannister of exceptionally good quality. The change from one type of section to another will recur several times in quite a small area.

Owing to the fact that the three deep valleys of the district—that of the Churnet, Consall Woods, and Ipstones—are cut principally in this portion of the Coal-measures, exposures are numerous, more particularly at the points where small streams flow into these larger valleys.

* See page 478.

Fig 20.

Comparative Sections of Coal Seams in the Cheadle Coalfield (by G. Barrow).



Ipstones and Froghall.—A long narrow strip of these beds occurs between Ipstones and Froghall, let down by two nearly parallel faults, and in this a number of boreholes were put down to prove the Froghall Ironstone, which in this area occurs at the base of the Coal-measures. Though the ironstone has been practically worked out, the borings are still interesting as showing the nature of the beds passed through. The exact position of these boreholes cannot now be fixed, as a series was made in each locality, and it is impossible to say to which the accounts refer.

A considerable number were made in the locality of Cloughhead, a farmhouse about a mile north of Froghall. These, while differing in minor details, show the persistent presence of certain beds of coal and bands of dark shale, which are sufficiently in accordance with the section, proved in the Engine Pit, close by for the latter to be taken as fairly typical of the district.

SECTION OF THE OLD ENGINE PIT NEAR CLOUGHHEAD. (FROGHALL.)

			ft.	in.
3	15	Grey and black shale	37	0
	14	COAL	0	4
	13	Hard fireclay and rock, shale at base	20	0
	12	SWEET OR SPLIT COAL { COAL, 1 ft. 1 in. SHALE, 6 in. COAL, 1 ft. 8 in. }	3	3
	11	Grey and black shale (bass)	19	5
	10	COAL	0	4
	9	Grey and black shale	31	6
	8	COAL (THE STINKING OR CRABTREE)	2	3
	7	Fireclay on white and grey rock	31	7
	6	Grey shale	2	9
4	5	COAL	0	3
	4	Grey and black shale (paper shale at base)	20	6
	3	COAL	0	4
	2	Grey and black shale passing to harder sandy shale	63	6
	1	Black shale 1 ft., Ironstone 1 ft.	2	0

Below this, the shaft was continued some 10 feet into grey marl.

All the strata recorded in the above section are visible at some part or other of the deep ravines between Froghall and Ipstones. Close to Froghall the banks of the stream are formed of the dark shales above the Crabtree or Stinking Coal. On the east side of the valley all the beds from this seam to the Kingsley Sandstone are present; but there are only isolated exposures, and no details can be made out. At the lime-wharf the Crabtree Coal crops out at about water-level, and from this point rises faster than the stream as we go north; so that a little above the rude dam, formed by the great shale-tip in the western valley, a foot-path

to Ipstones passes over the sandy beds below the coal. At this point there is a good section in the stream below which shows :—

	ft.	in.
Dark shales (No. 11 of above section)	20	0
Paper shale band - - -	1	0
Coal, 2 in. Smut, 8 in. (12 of above section)	0	10
White fireclay	5	0
Dark shale - -	10	0
Flaggy fine grit, having a cemented appearance at the base	10	0

This section is important, as the paper-shale band overlying the coal constitutes an horizon persistent over a very large area, and which once seen is readily recognised. Unlike the rest of the black shale it does not readily fall to pieces on weathering, but changes to a brown-paper colour, and in this condition it can be split open with a blunt knife, and thin sheets, like stiff brown paper, from two to three feet long, may be obtained. At times fish scales, and a small flattened *Lingula*-like shell are fairly abundant; but as a rule fossils are very sparsely distributed in the rock. It never contains, so far as we know, the masses of *Goniatites* and *Pterinopecten* so abundant in the other hard shale bands, and it differs also from the latter in the absence of pyrites. It is to the freedom from this readily decomposed mineral that the paper shale band owes its preservation.

Following up the stream towards Ipstones the hard beds (No. 7 sect., p. 245) above the black shale and under the Crabtree Coal form the sides of the small ravine till we reach the first houses of the village of Ipstones itself. Here a quarry has been opened in the gannister that so often occurs at this horizon. It may be noted that in this section no trace was observed of the thin coal (No. 10 sect., p. 245) which experience shows to be liable to great variations in thickness, and at times to disappear altogether. It must not, however, be inferred that it never existed, for there seems a strong probability, though this has not been proved, that many of these thinner coals were denuded after they were laid down. Only a short distance to the east of this stream a bore-hole passed through a hollow 2 feet deep due to the extraction of this very coal. The section also shows the variability of the hard beds that underlie the Crabtree Coal. At the south end of the exposure the bulk of the rock is a fairly fine sandstone, but close to the village it is mostly fireclay and gannister. This change in so short a distance is characteristic of the whole area, the zone being specially liable to lithological variation. The gannister and fireclays when present are usually of excellent quality.

Owing to the greater hardness of this zone it forms a step or feature in the stream banks, and this enables the position of the Crabtree Coal (No. 8 sect., p. 245) to be easily traced. To this fact the extensive nature of the workings in this neighbourhood is probably due. The coal was also pierced again and again in the shafts to the underlying Froghall Ironstone, and was often worked

for the engines at the numerous pits. The Crabtree Coal may be seen from the tip-heaps to be overlain by the persistent hard shale band rich in *Goniatites*, etc., that assists in the identification of this coal over a large area. The coal and shale together form the one persistent recognisable horizon in this part of the sequence.

To the south-east of the shale-heap in the Ipstones Valley the Sweet or Split Coal above the Crabtree, and another seam below it, have been cut open in the steep bank, but owing to landslips it is not easy to tell the exact thickness of either. They are too thin apparently to be worth working.

Ascending the east branch of the main valley a fault (p. 274) is crossed which brings up the Froghall Ironstone. The outcrop of this is marked for a considerable distance by a number of adits. Further north the sandy beds and gannister of the Crabtree Coal are seen close to the mill-dam, and about 200 yards beyond this is another section of the Split Seam, the thickness being the same as in the shaft given above (p. 245). Higher up the stream, the Crabtree again comes to the surface, close to an old adit, and the shales below the coal are also seen, but the ground beyond is much faulted, and the exact outcrop is difficult to fix.

South and south-east of Froghall a considerable area of these rocks occurs on the north side of the Churnet. Sections are numerous, and borings and shafts have been put down to prove the ironstone, and to work the Crabtree Coal. The ironstone is either too thin to work, or absent in this area, but the coal maintains its usual thickness. A little south of Eavesford the sandy beds below the coal form a grit, shewn on the map, with pebbles as large as those in the Third Grit, but the matrix is fairly fine. South of Whiston Eaves this rock is much finer and contains no pebbles. Over all this area the Crabtree Coal has been worked some distance in from the outcrop, and has always the *Goniatite*-shale roof.

A shaft, about 500 yards south of Eavesford, passed through three seams of coal below the Crabtree:—

SHAFT AT ROSS BANKS, WHISTON EAVES:—

	ft.	in.
Sand and clay	9	0
Grey bands and shale	4	0
Blue shale	35	0
STINKING OR CRABTREE COAL	2	0
Fireclay and rock	29	0
Black shale	3	0
COAL	0	10
Fireclay	8	0
Hard band on red marl	7	0
Black shale	2	6
COAL (? SHAFFALONG)	0	9
Black shale	9	0
Grey roach	9	0
COAL (? SHAFFALONG)	1	6

A boring put down by Mr. Johnson of Ipstones in the dell close by gives 40 feet to the hollow where the Crabtree has been worked; then 31 feet to a hollow where the roof has fallen into another coal; and then 29 feet to a red sandstone, said to be the top of the First Grit, though it does not seem deep enough.

A small coal seam about 7 inches thick, apparently above the Crabtree Coal, is exposed in the bank of the little stream close to the first railway bridge south of Froghall, but its position is not easy to fix owing to the faulted nature of the ground. The stream flowing south-east from Whiston Eaves gives numerous sections of the shales below the Crabtree, but these possess no points of special interest. Due south of Crowtrees a small slag heap suggests the presence of the Froghall Ironstone, but it cannot be thick, for trials have been made in the neighbourhood without success.

Near the farm of Eastwell the outcrop of these beds crosses to the south side of the Churnet. The northern boundary is a natural one, but the southern is a fault throwing down south. Sections occur in this outcrop in the streams east of Woodhead Hall, and again in the stream that flows down past Cheadle. The latter are in the black shale above the Crabtree Coal, while those to the east clearly show the beds associated with this coal, which has been worked. In some calcareous nodules from the tip heaps numerous fine specimens of *Goniatites* were observed, but they are very difficult to extract.* With the object apparently of proving if the Froghall Ironstone was present or not, a boring was made from the bottom of one of these pits. This must have pierced the First Grit, as a large quantity of water was met with, which still flows as a considerable stream in spite of the height above the base of the Churnet Valley. There could be no seam of ironstone present, but the water is markedly ferruginous.

Rather more than a mile east of Cheadle the shales of this part of the series are seen in the valley to the south of Hilltop Farm, and again in the hollow to the east; but as they pass in this direction under the Bunter sandstone no outcrops are known further south.

Returning to the Froghall area, and following these rocks round the margin of the coalfield, a curious outcrop of the Froghall Ironstone with a thin cover of shale occurs on the summit of the hill to the north-west of the railway station. The occurrence of these outliers was not known for a long time, and this is the more remarkable owing to the great amount of slag left from ancient workings, of which all record or even tradition is lost.

To the south of this hill a large fault throws the ironstone and overlying beds down into the valley, but the downwash is so

* Dr. Wheelton Hind determined two of these as *Goniatites* (*Gastrioceras*) *Listeri* and *Goniatites* (*Dimorphoceras*) *Looneyi*.

great that nothing is seen of the rocks till we approach the small stream that rises to the north-west near Ipstones; where a little below its junction with the main river the ironstone comes to the surface, and is said to form the bed of the canal close to the adit,* from which a small quantity of ironstone is still being mined for pigment. A little way up the small stream the First Grit comes to the surface, marking the position of the fault already referred to.

Further west many shafts were sunk to the ironstone, nearly all of which has been extracted. They proved the persistent presence of the Crabtree Coal, fairly uniform in thickness; and also of several smaller seams, two of which are very variable, but rarely as much as a foot thick.

The harder beds above the Crabtree Coal form the edge of a flat-topped hill on which Hillhouse Farm stands, and the outcrop of the coal can be fairly well traced.

In the small valley on the east side of Belmont Hall numerous sections are met with showing the nature of the lower portion of the series. The ground is much affected by faults, one of which is well shown on the east side of the valley not far from Pettyfields, and brings the shales below the Crabtree against a sandstone above that seam. The shale has locally slipped away from the fault face, leaving a curiously isolated sandstone scar. To the north of this no such slip has occurred, and the sandstone is consequently not seen, although it cannot be more than a few feet from the surface inside the bank face.

To the west of Belmont Hall some good sections of the beds about the horizon of the Crabtree Coal are exposed, and the gannister, which is of excellent quality, is quarried.

A little further up the Churnet Valley, on the same side, a small stream cuts through the basal shales of the series, and gives one of the very few natural sections of the Froghall Ironstone, here only about three inches in thickness. An equally thin seam was met with in the trial-shaft a little east of the stream, thus fixing the limit of the workable ironstone in this neighbourhood.

On the southern and western side of the Churnet, about and above Froghall, the lowest Coal-measures form the greater part of the steep banks of the valley. For some distance, however, the slips and wash from above prevent any rock being seen *in situ* till the woods north of Hazlecross are reached, where the traces of an old tram line indicate the outcrop of the ironstone, into which levels have been driven at intervals as far north as the flint-mill. Sections about the horizon of the ironstone are numerous, though slips are gradually obscuring these, and in time little bare rock will be visible. These slips occur at intervals

* Close above the adit is a little band of hard white grit or conglomerate; apparently that recorded in the Park Hall boring. It has not been seen elsewhere.

all down the hill face, and a fresh one will of course leave a bare scar for a time, of which several are at present visible. They are most numerous just below the summit of the bank at the top of the dark shales below the Woodhead Sandstone (p. 253). A few occur much lower down in the harder bands associated with the Crabtree Coal, which has been worked to a small extent.

Specially good sections of these rocks occur on the south bank of the stream that flows through Consall Woods, and joins the Churnet at Consall Forge. Although the sequence is locally affected by faulting, still on the whole the stream flows almost exactly along the strike of the rocks, and thus as the valley deepens lower and lower beds are exposed. For some distance above the point, where the long north and south fault crosses, black shale is the dominant rock, and this contains lines of small ironstone nodules, with at times marine fossils. On the east side of the fault a good section of the Split or Sweet Coal is exposed, the section being as follows:—

		ft.	in.
Mixture of sandy marl and gannister		4	0
Pale sandy marl		10	0
Smut, 3 in. COAL, 8 in. Smut, 4 in. Clunch, 1 ft. Smut, 3 in. Clunch, 1 ft. 10 in. COAL, 8 in.	Split Seam	5	0
Hard white clunch with particles of jet or coal		2	0
Hard clunch, base not seen		10	0

The clunch is a sandy material cemented by a little clay. It is coherent and devoid of bedding. Though softer than a sandstone it is much harder than an ordinary marly shale or clay.

A little further down the stream affords an excellent section of the Crabtree Coal with its *Goniatite*-shale roof. The coal can be followed till we reach a large scar in which the beds from some distance above the Split Seam down to this coal are laid bare, forming the most complete natural section in the district The Split Seam here consists of two bands of coal, each about 6 inches thick separated by 3 feet of fireclay and shale. A little further down the stream the beds above the Crabtree crop out, the section showing 30 feet of black shale with a *Goniatite*-band at the base. Under this is the Crabtree Coal resting on 3 feet of fireclay, succeeded by laminated and compact sandstones. These are totally unlike the harder material (gannister and fire-clay) worked on the west side of Belmont Hall.

The small scar formed at the angle in the bank, where the Consall Valley joins the main valley, shows the paper-shale bands some distance below the Crabtree Coal described on page 246. It is here underlain by a thin coal smut, while a little above

it are several bands of sandy material closely approaching gannister in appearance and composition. A considerable distance up in the bank a shaft was sunk to the Froghall Ironstone, which shows the absence of any seam of coal below the Crabtree. It also shows the great thickness (93 feet) of loose material that tends to accumulate on these steep banks, largely no doubt due to landslips as well as downwash.

On the north side of the Consall Valley there is a considerable area occupied by this portion of the sequence, but only a few good natural sections occur. Owing to the fact that the beds below the Crabtree Coal are harder than the rest, they were often cut open to make the tram roads for the old ironstone mines, and by their aid the outcrop of the coal can be traced over a considerable area. The ironstone was extensively mined, as the numerous shafts indicate. The workings proved the area to be greatly cut up by faults, of which the majority are shown on the map. The Crabtree Coal was met with in every shaft sunk deep enough to intersect this seam. It varied in thickness from 1 foot 6 inches to 2 feet, and was worked for the engines where convenient to do so. It was always highly pyritous but gave a good heat, and coked well. This local mining of the seam has given rise to a number of patches of waterlogged ground, which will be a source of danger and difficulty if the seam be more extensively worked at some future time.

In addition to the shafts sunk to the ironstone, some borings were put down to prove it in Ladypark Wood, close to the stream, and west of the fault shown on the map. One of these met with the ironstone at a depth of 95 yards, the stone being only 7 inches thick and too thin to work. The second, some distance further west, proved the seam altogether absent. Some additional borings were made in the fields near the road to Wetley Rocks, which proved a coal, said to be the Crabtree, at a depth of 12, 14 and 20 yards, but no ironstone was found.

The outcrop of the series on the western side of the Cheadle basin is difficult to understand, as the rocks rapidly change in character, and are besides greatly faulted. The high dip also produces a steep featureless country, which is further obscured by down wash. The shales can be seen occasionally in a few stream sections, and have been excavated to a considerable extent for marling the fields. The Crabtree Coal was not met with in any of the pits, which extend almost to the Dilhorne Fault (p. 275); so that it seems reasonable to suppose that this seam, like the Third Grit Coal, has died away. To the south of this dislocation these rocks are covered by the Triassic beds, and nothing is known of their further course.

From the above account, it will be seen that the Crabtree is the only seam of any thickness that is at all persistent over the greater part of the area. It has a thickness varying from 1 foot 6 inches to 2 feet 4 inches over all but the western district.

It has been extensively worked at different times, and it is doubtful how much of it is left except as isolated patches surrounded by waterlogged "Old-man." In the area north of the Consall Valley a small portion has been worked for the hauling engines of the old mines, but the bulk of it is left. It is, of course, untouched over the greater part of the Cheadle area, but whether it would ever pay to work when coal becomes scarcer is a difficult matter to decide. It seems to be a quick-burning coal and cokes easily. It may some day be possible to extract the pyrites and coke the residue.

The Froghall Ironstone.—This seam of ironstone, which has been referred to above, lies either directly on the First Grit or may be separated from it by as much as 15 feet of shale. With the exception of a few patches that are worked for making red paint, the seam has been practically worked out. It was deposited in the form of an extremely thin lenticle of somewhat irregular thickness, which was roughly elliptical, the longer axis of the ellipse trending east and west. The southern limit has been proved at the west end by the borings already referred to in the Consall Valley, near the stream flowing north from Kingsley Moor. It was followed till it was too thin to work both at Hazlecross Pits, and at some pits close to Kingsley Village. A boring proved its southern termination again at Froghall, and only a trace of it was met with at Whiston. To the east of Ipstones it passes to a curious admixture of coal and ironstone, which did not pay to work. Beyond this for some considerable distance, the limit to the north, is the natural outcrop, but close to the Churnet it has been proved to die away to a few inches before reaching the outcrop. In order to prove if this seam came on again a boring was put down by Mr. Almond from the bottom of Park Hall Pit (Sect. No. 76 Appendix), and this corroborated the evidence already given that the seam does not extend south of the line described above.

That this seam owed its existence to local conditions, which tended to recur, seems to be shown by the fact that in the area where the seams become a mixture of coal and ironstone two other similar admixtures, as noted above occur between the First and Third Grits. This association suggests some special condition for its occurrence, and it seems that filtration may be partly the cause. For instance, if a delta be covered with a dense vegetation of a reedy or fern-like nature, the mass of vegetation will tend to filter off all sediment while allowing water to pass through. The coal may possibly be formed by decomposition *in situ* of the vegetable matter, the shells once present being completely decomposed by solution in water highly charged with carbonic acid, and the lime replaced by iron. As Mr. Sorby has so ably shown, lime produced from certain shells is peculiarly liable to be replaced by iron.

Some details of the mode of occurrence of this ironstone are published in the "Iron Ores of Great Britain," by Warrington Smyth, Part IV. pp. 277–279, and an analysis is given by Mr. Dick, p. 291.

3. Woodhead Coal and Sandstones.

The rocks of this group possess such well-marked characters that it has been possible to trace them continuously over nearly the whole area of the exposed coalfield. A boring put down at the bottom of the shaft at Park Hall Colliery penetrated all the members of this group, and proved the succession to be as follows in descending order:—

	ft.	in.
Black shale or bass	10	0
WOODHEAD COAL - -	2	10
PRICKING AND OUSTER COAL -	1	0
Nodular sandy marl (Conglomerate rock)	10	0
Dark shales with harder bands in lower part	40	0
Flaggy sandstones with thin partings -	170	0
Finely fissile grey sandstone - -	50	0
Fine grey sandy shale (dark shale below)	40	0

The rocks forming the lower members of the group may be briefly described as a thick mass of flaggy sandstone (the Woodhead or Kingsley Sandstone), passing through the stage of a very shaly sandstone to a sandy shale. The whole, in fact, forms a perfect transition from sandstone to the dark shales of the group below. There is no other rock in the district at all like this Woodhead flaggy sandstone, and a good outcrop of it is unmistakable.

The bed, locally known as the "conglomerate-rock," is a rather hard sandy shale, portions of which are cemented together so as to form ferruginous balls, harder than the rest of the bed. From the presence of these balls the rock has acquired its name. The shale on which this rests is softer and not quite so dark in colour as the bass. These dark shales above and below the coal serve to distinguish it at once from any seam at a higher horizon.

The Woodhead Coal is about 2 feet 10 inches thick, and of fairly good quality. It is essentially a non-bituminous coal and can be taken out in large blocks. At the base of the seam is some shale and shaly sulphurous coal, about 1 foot thick in all, which is taken out in working the coal.

The peculiarly hard black shale or bass at the top of this group makes an excellent roof in the coal workings. It can be easily recognised in the field, both from its nature and from the band at its base, locally known as the Fish-bed, which is so peculiarly full of these remains. The amount of them may be best understood by walking along the line from the Foxfield Colliery where the metals are ballasted largely with this band. About every third bit of shale, if not too decomposed, will be found to contain fragments of fossil fish. At the Kingsley Moor

Pit they are equally abundant, but further to the south and east, though still abundant, they are present in smaller quantity.

Natural Exposures or Outcrops of the Group.—The coal with its associated rocks is cut open in the side of the small stream that is crossed by the by-road from Dairy House Farm to Above Park, the road leaving the stream close to the point where the coal crops out. The latter is here 2 feet 9 inches thick; the top and base being clearly seen. A little further north a fault throws the beds down, and the coal is seen at the surface again higher up the stream, as shown on the map. Below the coal an excellent section of the flaggy sandstones occurs here. The group of beds can be traced in a southerly direction towards the by-road already mentioned and the coal has been cut open in forming a drain. The outcrop ends against the fault referred to above, which brings up the flaggy sandstone against the coal. After crossing the fault the flaggy sandstone can be traced for some distance and a trial shaft was sunk in it. The further outcrop of the coal to the south could not be traced, nor could the sandstone be followed far beyond the trial sinking.

A complete section of the Woodhead Coal and its associated rocks occurs in the small stream that rises on Kingsley Moor, and flows north through Hollins Wood. It begins at a point about 500 yards north of the meeting of the three roads. After passing some fissile sandstone, soft sand-rock, and the typical pale marly shale, a small adit is reached driven in the Woodhead Coal. The seam is still visible, but the underlying beds are covered with the spoil from the adit. A few yards further on a fault is seen throwing down to the north and repeating the beds, so that at the junction with the next small stream the upper part of the bank is formed of the black bass above the coal, which is well exposed here, and is about 2 feet 9 inches thick. Below the coal is a few inches of cannel shale, like that under the Rider Coal (p. 260). This is underlain by the slicken-sided shale and impure coal known as the "Ouster." The conglomerate rock occurs beneath this, and is about 6 feet thick; it overlies a shaly clunch and lumpy shale, which passes to a mass of dark shale some 30 feet thick. This rests on the typical flaggy Woodhead Sandstone of which a complete section is seen, and the gradual passage from the base of the sandstone to the dark shale of the group below is well shown.

To the east of this stream the rising ground is formed by the sandstone, and the traces of old outcrop workings enable the position of the Woodhead Coal to be traced as far as Hazles. Here the ground is somewhat obscured by faults, proved in working the Froghall Ironstone, but nearer Kingsley the coal can again be traced by old crop workings. The village itself stands on the sandstone, in which there are numerous sections. The typical thin-banded rocks are well shown in a quarry on the

edge of the Churnet Valley at the south-west corner of the plantation due north of Kingsley.

Close to the brick bridge, where the footpath crosses from Kingsley school grounds, the stream has cut open the dark shale below the coal. Between the bridge and the small plantation close by a band of indurated mudstone occurs in the shale, which contains numerous fragments of fossil Fishes, as well as abundant specimens of *Carbonicola* and *Spirorbis*. A few feet above this mudstone is a ferruginous nodular band crowded with casts of *Anthracomya*. A little higher up in the series, but lower down the stream, is a lenticular, speckled, siliceous band containing numerous plant remains. The sandy material below the coal occurs a little further on, and then the coal itself crops out in the bank, succeeded by the black bass, and still further south by the grey shales of the group of beds above. A slight change in the dip brings the coal to the surface again, a little above the Cheadle and Froghall road. To the north-north-west the coal lies close to the surface for some distance, and crops out again about 200 yards north-east of Shaw House. It here covers a rather broad strip of ground, and at its base is a thin band of cannel shale containing compressed shells, mostly *Carbonicola*.

The sandstone is seen in the sides and bed of the stream for some distance below the Cheadle road, after which it is faulted up and fragments are then seen in the hedge sides on the west side of the valley.

To the south of the fault that crosses by Woodhead Hall the black bass has been dug out to form the dam for the fish ponds, while fragments of the Kingsley Sandstone cover the fields about Woodhead Farm and Abbotshay. In addition, small sections of the sandstone are seen in the sides of the old tram line near the hall. Further south the position of these beds is for a short distance completely obscured by the belt of Bunter sandstone; but to the south of this strip the Woodhead Rock is repeatedly cut into by small streams that rise about Hilltop to the north of the Alton road. The outcrop workings of the coal can be traced over most of the area to the east and south-east of Cheadle. Close to the farm of Rakeway, on the Croxden road, is a rather deep pit from which shale has been dug for marling the fields, and many fragments of coal are seen about the quarry sides. The shale seems to be the black bass and the coal the Woodhead, but this was not clearly proved. Beyond this the coal and sandstone pass under the Bunter sandstone, and their further course is unknown.

In addition to the outcrop of these beds, within the Cheadle basin. there is a second outcrop due to a sharp syncline in the Churnet Valley, which corresponds to the ending off of the large north and south faults of the Froghall and Ipstones area. The outcrops of the sandstone and coal on the western edge of this syncline are shown on the map. The coal can be easily traced owing to the numerous sections shown in the

small streams that drain east into the Churnet; indeed, some of the oldest workings in the Woodhead Coal occur in the neighbourhood of Woodhead Hall, and the seam has derived its name from this fact. Of the many sections north of Woodhead Hall one of the most interesting is that in the streams due east of Thornbury Hall, which cut through the whole thickness of the sandstone. The rock is, on the whole, less flaggy than usual, though it forms a succession of features due to the presence of softer partings. In addition, parts of it are cemented by carbonate of iron or lime, and are then intensely hard. To the south of Woodhead Hall the coal forms a small outlier on the crest of the small anticline that separates the main Cheadle portion of the coalfield from that in the syncline to the east. This syncline has already flattened considerably before the Triassic rocks close by are reached, and probably does not extend far under them.

Details of the Woodhead Coal.—This coal has an average thickness of about 2 feet 10 inches, and, as a rule, is of fairly good quality. Its extensive working is in part due to the nature of the beds immediately above and below it. These form an excellent roof and floor, and the cost of timbering is unusually small. In this respect it contrasts strongly with the seams above, most of which have either a bad floor or roof, or both, and the expense of timbering is much heavier. The workings near the outcrop in the northern and eastern area are of great antiquity, and, as a rule, no details of them can now be obtained. In the western and south-western part of the coalfield, however, the outcrop is largely obscured by wash, and possibly by faulting, and, in consequence, the coal is mostly untouched. The most south-westerly portion of the outcrop occurs under the Bunter, and still less is known about it.

The coal in the small detached area to the east lying in the syncline referred to above has been worked out. In the main basin, in the area north of the Dilhorne Fault, most of the coal has either been won, or is in process of extraction by the Foxfield, the Hazlewall, Kingsley Moor, Park Hall, and Cheadle Park collieries. In the area intersected by the east and west faults to the south of Dilhorne none of the coal has yet been touched, nor under the narrow strip of Trias sandstone at Cheadle.

To the south of these faults in the Cheadle district the coal has been won as far west of the outcrop as the Birches Colliery, where the workings were stopped by a large fault trending north-north-west not far from the shaft. About Cheadle Mill and Rakeway to the south-east of Cheadle the coal deteriorates, and is apparently not worth working.

In addition to the area being worked there is thus left the whole of the coal south of the Dilhorne Fault, except the small

part to the south and east of Cheadle. There must therefore be an area of at least two square miles still remaining. This calculation is based on the supposition that in the southern area the coal crops out to the west as it does in the Foxfield area. But it is quite possible that this may not be the case, and the coal may continue on into the Potteries Coalfield. The extent of the seams in this south-westerly direction can only be proved by boring. In any case the coal must be overlain by a greater or less thickness of Triassic rocks, which in this district contain a large quantity of water, and may prove a considerable obstacle to further workings in this direction.

2. *Lower Pale Group.*

To the north of the Dilhorne Fault and the tongue of Bunter at Cheadle these rocks cover a considerable area, roughly quadrangular in shape. The outer or basal limit is practically the Woodhead Coal, the outcrop of which is shown on the map. A few small exposures occur on the western part of the coalfield south of Dilhorne, but the Coal-measures here are for the most part buried under the Triassic rocks. On the east of the Tean and south of Cheadle another fairly large area is composed of these beds, but they are again buried under the Bunter in the vicinity of Huntley.

The greater part of the group is penetrated in the Foxfield Shaft (Fig. 20, p. 244) which starts practically at the Dilhorne Coal This coal is some little distance below the top of the group, which has never been proved in any shaft sinking, but by the aid of the railway cutting at Cheadle, and information obtained in working the Dilhorne Coal, the complete succession can be obtained.

Exposures of the Group at the Surface.—In the northern part of the outcrop of these rocks good sections are met with in several of the streams. Commencing with the one that flows between Dilhorne and Cheadle at Park Hall, and ascending the eastern branch, a good section of the Dilhorne Coal is seen not far from the farm. The whole of the seam is not exposed, but the base can be accurately studied. It consists of a 9-inch hard band, containing films of soft coal and jet. This rests on clunch composed of fine sand grains cemented by a small quantity of argillaceous material. It contains rootlets and is devoid of bedding. A little above Park Hall Colliery some of the typical pale-weathering marly shales, the dominant constituent of the group, are seen. North of Parkfoot there is an almost continuous section for some distance mainly in this material; the softer part contains numerous balls of impure ironstone that weather to hollow cases. Just below Holleygrove is a thin coal (4 inches) with a hard band above and clunch below. Grey and dark shales are seen some distance further up, and these must

be close above the Stinking or Alecs Coal, as from the account of the shaft there are no such shales till we reach this coal. A fault proved in the Hazlewall Colliery repeats this shale, so that it occurs again in the stream, and about the roads close to Above Park, where the old workings in the Alecs Coal can still be traced. The peculiar pale weathering of the beds of this series is well shown about the banks of the brooks, and a particularly good section occurs in the brickfields adjoining the Hazlewall Colliery. The section here is—grey shale, a few feet; Foxfield Coal, 18 inches; grey shale, 10 feet; sandstone, 14 inches; with soft grey shale below.

Starting again from Park Hall, and ascending the west branch of the stream (Godley Brook), typical pale rock is first seen, and then the south-west bank is occupied for some distance by the base of the Dilhorne Coal. Taking the right branch at Birchenfields some low mounds are seen on the west side of the brook, which the spoil-heap shows were workings in iron nodules, and possibly the thin continuous band seen in the banks of the stream. At the base of this band are some much crushed shells resembling *Carbonicola.* This bed (? No. 8 of the Foxfield Shaft) is repeated by a fault a little further on. The small seam of coal (? No. 9) is also exposed here. Above this is soft sandstone and sandy marl for some distance. Below Hatchley a few feet of dark shale is associated with a curious rock, composed of mud or shale cemented by brown ironstone material. Where the iron is at a maximum the bed is intensely hard, and in addition contains threads of jet. This rock is violently contorted, but no actual fault was observed, though it lies almost in line with a fault proved further east. No fossils were found. After passing some more of the pale rocks a dark shale is reached, and numerous pits are seen round about. These were sunk to the Alecs or Stinking Coal, the top of which is exposed in the bed of the stream. The dip which hitherto has been to the south-west now turns round gradually to the south-east, and is at a rather higher angle. A little north of Dairy House the stream flows in a small gorge cut in the sandstone and shale above the Woodhead Coal. A fault crosses a little further north, and repeats part of the series, for the Rider Coal is met with higher up the stream. Still higher up is the outcrop again of the Woodhead Coal, underlain by the typical flaggy sandstone. The two small streams that flow down through the woods at Foxfield Colliery, and unite to form the west branch of Godley Brook, both give good sections. In Pearcroft and Foxfield Woods the steady increase in dip as we go west from the colliery is specially well shown. At the shaft it is about seven degrees to the east. From this point it steadily rises till at the head of the little stream it is at least twenty degrees in the same direction. This increase in dip is even better shown in the next wood to the south (Broomyclose Wood), for here the section continues further to the west, and in the last rocks seen the dip

is about forty degrees. In both woods the outcrop of the Stinking or Alecs Coal is exposed with the beds below and above; while the Foxfield Coal also crops out in Broomyclose, about 300 yards below the higher loop of the railway. To the south of this wood is a narrow plantation with a small stream flowing south to the fish ponds. On the west edge of this plantation a coal has recently been cut open in draining. From the nature of the dark shales associated with it this should be the Woodhead, but its identity is doubtful. It will be noted in examining the rocks in the woods, and still more the shales further west, that many of the beds have a pronounced red colour not observed in the rest of this area. It is possible that this is due to staining from the red rocks that once covered the whole district. In the streams that rise about Kingsley and Kingsley Moor and unite on the east side of Cheadle, numerous sections of the Lower Pale Series occur, but they are disconnected, and the horizon in them is usually difficult to fix. In addition to the pale rocks, which are indistinguishable from one another, the grey shale above the Stinking Coal is seen close to Harewood Hall, and the coal is cut open in the bank of the small stream, about 500 yards northwest of Booth Hall. At this farm a bed of sandstone makes a good feature that can be traced for some distance, and in a small pond close by is a little band of dark shale, said to be some 15 feet above the Cobble Coal, thus fixing the position of that seam.

In the stream below the Booths a thin seam of cannel shale occurs at several points, but its position cannot be ascertained from the sections of the shafts. It should be some little distance below the Cobble Coal. Apparently the same bed is seen in the small sandstone quarry close to Shaw; it is here some eight feet above the sandstone. Numerous small exposures of the pale rocks occur on the sides of the fish ponds near Shaw, and the traces of coal seen on the edge of the most westerly may be the outcrop of the Rider Coal.

In the stream that flows down from Hazlecross, past Kingsley to Cheadle, numerous sections occur, the most interesting being those associated with the coal seams. Those involving the Woodhead have already been given. The Cobble Coal is twice seen. About Hazlecross it occurs about the bed and banks of the stream (see map), and is again repeated by faulting in the stream close to the footpath from Kingsley Moor shaft to Hazlecross.

Much further south another section is shown in the stream due east of Broadhay, which is as follows in descending order:—

Pale marls.
Coal, 1 foot.
Cannel-shale, 1 foot 6 inches.
Fireclay, 4 feet.
Sandstone, base not seen.

The cannel shale contains much bituminous matter, and parts of it can be lighted with a match. *Carbonicola* occur

in it, as in the Kingsley area, but the fossils are much flattened. The beds at the southern part of the section are flat, but to the north they rise rapidly, marking the position of a fairly large east and west fault. In the ditch on the north side of the long plantation that reaches nearly to Woodhead Hall, and close to the stream, the Rider Coal crops out for a considerable distance; it has been recently cut open in draining, and shows well the imperishable nature of the cannel shale. Between this locality and Huntley numerous exposures of the pale rocks occur both in the stream and in the brickfields, but unless there is some special band present it is impossible to tell their exact horizon. The cutting at Cheadle Station exposes perhaps the most important section in the whole district. At the west end, and dipping west, are some sandstone bands in marly shales, the latter containing some ferruginous nodules. These beds are succeeded to the east by a considerable thickness of pale marls, with a two-foot band of dark shale below. The top of this shale is somewhat indurated, and contains numerous fossils. Below the dark shale there are some three feet of pale marl with another thin dark shale band at the base, resting on a coal seam. This is the Huntley Coal, and is about four feet thick. Below the coal there is more pale marly shale containing small ironstone nodules, and having a seam of cannel shale at the base. Close to the cutting on the north side are the old shafts (Majorsbarn) put down to work the Woodhead Coal, but which were sunk only to the Alecs or Stinking Coal. The depth to this seam proves clearly that the coal exposed in the cutting is the Dilhorne Coal, but it has thinned away so much that the fact has hitherto not been recognised.

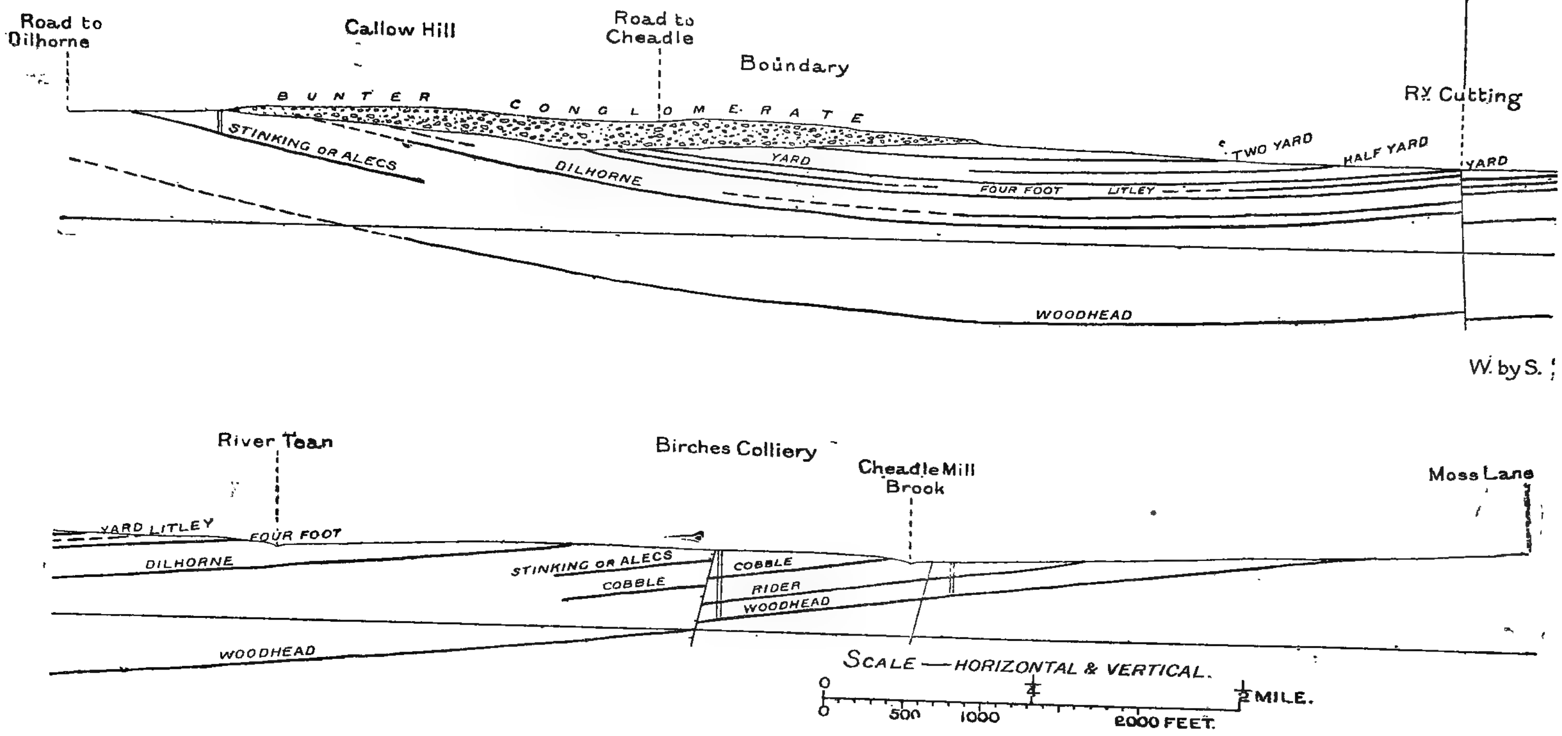
Details of the Coal Seams.

The Small Seams between the Alecs and the Woodhead Coals.—Between the Alecs and Woodhead Coals, in the Foxfield Shaft, four small seams were met with—viz., the Foxfield, the Mans, the Cobble and the Rider. Of these seams, only the Cobble has been worked to any extent.

The Rider Coal.—This seam is usually rather over a foot thick, and has a cannel-shale base. The outcrops of it have been noted already. It is thin and not easily separable from the shale below, into which it seems to gradually pass; consequently, so far as can be ascertained, it has never been seriously worked. It obviously covers the same area as the Cobble Coal, but extends slightly further in all directions around Cheadle.

The Cobble Coal.—This seam is usually of good quality. It has consequently been more extensively worked where not too far beneath the surface. Its exact outcrop cannot be fixed, but in the northern part of the area it extends a

FIG. 21.
SECTION ACROSS THE CHEADLE COALFIELD.
By G. BARROW.



little beyond the Kingsley Moor Shaft; a line drawn from this shaft parallel to the outcrop of the Alecs Coal in a south-west direction gives a very fair idea of its extent and outcrop. To the south and east of Kingsley Moor the seam is just below the surface at the disused Longhouse Shaft, and the outcrop must occur on the east side of the present tramway. South of the fault shown on the map near Booth Hall the old Shaft started just below the Cobble Coal, and the outcrop is at or a trifle west of the tram-line. It is not present in the old Ladywell Shaft, but there are numerous traces of some very old workings near here that may have been in this seam. Further south the ground is much faulted, and it is not possible to fix the outcrop, but the old disused pit known as Rimmons penetrated the coal at a depth of 14 yards from the surface. From this point there is a considerable area more or less dotted over with small mounds, showing the position of the numerous shafts sunk to this coal. The mounds extend to the Woodhead coal-staithes and some distance to the north, while they are bounded to the south-west by the little stream flowing past the staithes.

The position of the coal under the narrow strip of Bunter near Cheadle is not known, but to the south of the town the seam has been worked near the surface, and traces of some of the old shafts can still be made out, from which the approximate outcrop shown on the map has been determined. No record of any workings can be obtained further south till we reach the Eaves Farm in the Huntley district, where the seam was worked for some years and where the outcrop workings can be easily traced. It appears to have been followed some distance to the dip, and was last worked from a shaft about 50 yards deep, sunk at the back of the cottages opposite Mobberly; but the coal was followed only for a short distance. That this seam was the Cobble seems certain; for on the east side of the field opposite Huntley Lodge Gate a shaft was sunk to a depth of seven yards to a seam locally known as the Four Foot Slack. From its thickness and characters this could only be the Alecs or Stinking Coal; the Eaves Coal, which is the proper distance below, possesses exactly the characters of the Cobble. It was from 18 inches to two feet thick.

On the western side of the coalfield little is known of this seam. Owing to the high dips prevailing to the west of the Foxfield Shaft there is some doubt if it is the coal seen in a drain recently cut open on the west edge of a small plantation, about a quarter of a mile north-west of the bend in the road at Dilhorne. There is so much dark shale associated with this Coal that it appears at first sight to be the Woodhead, although so far as can be ascertained it is too thin to be this seam.

South of the Dilhorne Fault the small shaft already referred to, west of Callowhill, shows that the seam extends some distance west of the Dilhorne and Forsbrook road; but further

south nothing is known except that it must extend west of the Alecs Coal, but not so far as the Woodhead.

The uniform good quality of this coal makes it likely that as thicker seams become scarcer it may be more extensively worked. North of the Dilhorne Fault it extends over the whole area within the outcrop of the Alecs Coal, and somewhat beyond. In the northern part it reaches to the road due north of Hazlewood Colliery.

The seam occupies an oval basin, the longer axis of which lies north-north-west and south-south-east, and is about four miles long; the shorter axis being some two-and-a-half miles long. Cheadle lies about the centre of the east margin of this basin, and only the fringe of the coal on this side has been worked.

The Alecs or Stinking Coal.—The next seam of any importance is the Alecs or Stinking Coal; the latter name arising from the sulphurous smell it gives when burning. It has been worked in several places near the outcrop. The most northerly workings are near Dairy House, and south of Hazlewall; and by their aid the outcrop can be traced for some distance. Some old shafts near Harewood Farm are said to have been in this seam, but no out-crop workings are now visible. Traces of shallow pits are met with close to the Cheadle road near Harewood Hall, and trials of the coal were made close to the present Park Hall Colliery. It was here found that the underclay was so soft that it tended to swell up and close the workings, and the amount of timber required to keep them open was too great to enable the seam to be worked at a profit. In the neighbourhood of Foxfield and Dilhorne the coal has been worked to some extent, but the workings never penetrated far from the outcrop, showing that it did not pay to work at any considerable depth.

South of the Dilhorne Fault, in the Dilhorne area, a shaft was sunk which reached this seam at a depth of 50 yards. The old shaft lies on the east side of the Forsbrook road, and about 500 yards west-north-west of Callowhill Farm. The beds were found to rise to the west at the rate of 1 in 7. This shaft is of considerable importance, as it shows that the Dilhorne Coal cannot extend as far west as this, while the Woodhead must extend considerably further. The coal in the shaft was of no better quality than usual, and the amount taken out was small.

Still further south, nothing is known of this seam, as its outcrop is entirely concealed by the Triassic rocks.

On the eastern side of the basin, near Cheadle, the outcrop is cut out for some distance by a fault proved in the Birches Colliery; but, as already stated, the coal was reached in the Majorsbarn Shaft further west, where it was not considered worth working. Its outcrop was met with some 300 yards to the north-east of Huntley Hall, and it was worked to a small extent, being locally known as the Four Foot Slack. But as usual it was not followed far in from the outcrop.

The Mans Coal.—This coal has not been identified at the surface, and there is no certain record of its having been worked anywhere.

The Foxfield Coal.—This crops out in Foxfield Wood, near the Foxfield Shaft, and again in the brickpit at Hazlewall. It has been proved in other shafts north of the narrow belt of Bunter sandstone, and appears to have an average thickness of some 18 inches. The fact that it has been so little worked, even when close to the surface, suggests that it is of moderate quality. It lies between the Stinking or Alecs Coal and the Woodhead, as already stated, and its extent and position can be roughly inferred from the outcrop of these two seams.

The Dilhorne or Six Foot Coal.—This has been worked out north of the Dilhorne Fault. In the course of these workings a shaft at Old Engine Farm proved a small two-foot seam of coal, of good quality, about 60 feet above the Dilhorne. This fact is of importance, as a similar seam was met with above the Huntley, or the coal seen in the Cheadle Railway cutting. The Dilhorne Coal is thrown down by the great east and west fault; but, owing to the fact that this fault corresponds nearly to the oncoming of the unconformable Bunter sandstone, the outcrop of the coal does not reach the surface for some distance to the south of the fault. South of Cheadle, there being no Bunter sandstone, the seam again comes naturally to the surface, and is the bed seen in the Cheadle Railway cutting. Owing to its diminished thickness it was not recognised as such; but, as stated above, the Majorsbarn Shaft shows that the Cheadle Seam is at approximately the same height above the Alecs Coal as it is in the Foxfield Shaft. The workings of this seam almost reached the Cheadle cutting, and proved it to be the Huntley Seam. In working the Huntley Coal, a two-foot bed of good coal was met with corresponding to the Two Foot Seam in the Dilhorne area. Moreover, the seam at Cheadle continues to thin towards Huntley, showing that the diminished thickness as compared with the Dilhorne area is what would be expected at Cheadle. Putting all the evidence together, there can be little doubt that the coal visible in the Cheadle cutting, or Huntley Coal as it is called, is the same as the Dilhorne Coal. The observed dip in the railway cutting enables a rough estimate to be formed of the thickness of the beds between the Four Foot Coal, which crops out close to the Tean, and the Huntley Seam; this must be somewhat less than 200 feet. The Huntley Coal was worked from shafts in the neighbourhood of Huntley, and followed almost to Majorsbarn. At the former place the seam is about three feet thick, but thickens slowly towards Cheadle. No faults of any size were met with, and the beds dip about two inches to the yard to the west-south-west.

With the exception of the portion taken out in these workings the Dilhorne or Huntley Coal is intact over the area south of the Dilhorne Fault. It must extend to the west of these old workings as far as a line drawn south from Dilhorne Church through Callowhill. South of the Cheadle road, it is difficult to say how far it extends to the south-west under the Triassic rocks; but it must certainly cover an area of at least four square miles, with an average thickness of about four feet.

This seam has been confounded with the Two Yard or Six Foot Coal at the top of the next group of beds; but the fact that the Dilhorne Fault throws down to the south makes the idea impossible. The fact that the Dilhorne Coal underlies the whole of the Delphouse area does not seem to have been suspected up to the time of the Re-survey; but it has now been proved by actual sinking to exist under this area (*Coll. Guardian* for May 27, 1904, and *Geol. Mag.*, 1904, p. 323).

3. *The Upper Pale Group.*

This group is confined to the western part of the Cheadle Coalfield. Its occurrence is limited to the north by the large east and west fault that passes from Dilhorne to the northern edge of the Bunter at Cheadle. This throws down and brings on these higher beds, for which reason they are sometimes locally known as the "deep measures." To the east, the small stream flowing past Park Hall Farm and Brookhouses to join the Tean at Huntley approximately corresponds with the outcrop of the Four Foot Coal, though this seam frequently crops out a little on the east side of the stream. To the west the outcrop of the Yard Coal has been proved under the Bunter sandstone in the Dilhorne area, and that of the Four Foot in the Delphouse area, as shown on the map. But south and south-west of Delphouse, although the workings in the Yard Coal have extended as far south as the middle of Huntley Wood, nothing is known of the outcrop of the lower coals beneath the cover of red sandstone.

The following section shows the thickness and nature of this part of the series:—

SECTION OF THE BEDS IN THE DELPHOUSE AREA:—

	ft.	in.
Clay	4	0
Coal and smut	2	6
Marl	8	6
Roach (sandy shale) streaked with sandstone	20	0
Grey shale (falls to wet clay)	12	0
COAL, The Two YARD	5	0
Ouster coal and pricking	2	8
Clunch	6	1
Roach and rock binds	18	4
Fairly hard sandy rock, not bedded	27	0
GETLEY COAL (Useless)	2	0
Rock, compact sandy material	13	0
Soft grey shale, hard black film at base overlain by shell marl band	7	0

	ft.	in.
COAL, HALF YARD	2	6
Clunch - - -	6	0
Roach and rock binds -	16	0
Hard white rock, black streaks	24	0
Grey shale, falls to clay	12	0
Black shale	0	6
COAL, THE YARD	3	9
Fireclay	1	6
Hard clunch	6	0
Rock - -	15	0
Very hard white rock - - -	8	0
Grey shale (seam of dark fossiliferous shale at base) -	19	0
COAL, THE LITLEY - -	2	9
Pricking, 3 in.; Ouster coal, 2 ft.	2	3
Grey clunch	6	0
Rock -	12	6
Grey shale - -	14	9
COAL, THE FOUR FOOT -	3	6
Total - -	282	0

A great drawback to the working of the coals in this part of the series is the soft nature of the beds associated with them. While some of them have a fairly good roof, nearly all have a bad floor, formed by the white or pale measures already referred to. Even when dry this is soft, and tends to swell up and close the workings, particularly when water is encountered. Owing to the great extent of "Old Man" referred to below (p. 267), it is at times almost impossible to keep the water out.

The Litley and the Four Foot Coals.—These seams have been mined to a considerable extent, but the workings are rather scattered. As the coals are of rather poor quality they do not seem to have been followed where difficulties were encountered. Close to Parkhall Farm a shallow shaft was sunk to the Four Foot, and it was followed to the fault already referred to as seen in the tunnel-cutting (p. 265). On the opposite side of the stream these coals lie in a trough, and though they have been followed in from the outcrop on both margins of the trough it is not possible to find out exactly how far they have been worked. On the south side of Cheadle much of these coals has been won for a certain distance south of the fault, but beyond the Wonder Pit little is known of them, and they have probably not been mined.

The Yard Coal.—This is the best seam in the series, and consequently has been extensively mined. The outcrop, as far as is known, is shown on the map. On the eastern side, south of the Cheadle road, there is a double outcrop due to a fault that throws down some 35 feet, and may be seen in the railway cutting at the entrance to the tunnel. The area over which this coal extends is divided by faults into four parts. The first and most northerly of these lies immediately south of the Dilhorne Fault, and a considerable number of pits were sunk to it, the remains of the more recent of which can still be seen. No record of the

oldest, near the eastern outcrop, can be found. Close to the edge of the Bunter, at The Dale, south of Dilhorne, a shaft was sunk, from which this seam was followed to the outcrop under the sandstone, and there seems no reason to doubt that it has been worked out in this strip.

In the next strip several shafts were sunk, and one of these is still open. The coal to the east has been won, but whether the coal has been followed from the open shaft to the outcrop under the Bunter we have been unable to ascertain. The fact of the pit being left open suggests that this was not the case.

The third strip lies between two faults. Close to the four cross roads a shaft was sunk to a depth of a hundred yards to the coal, which was taken out on the rise or west side. On the dip the workings do not extend far, and there is a strip left, the exact size of which could not be ascertained.

In the area immediately south of the fault at the Cheadle road much of the coal has been won; but further south, beyond the Wonder Pit, much of the coal is left. It is impossible to say how far south of the Draycott Cross ridge the seam extends, as nothing is known of it; on the north side of the ridge it has been worked to some extent, but the workings are old, and no plans could be found.

The Half Yard Coal.—This seam varies somewhat in thickness but the average may be given as two feet six inches. It is of fair quality. The outcrop south of the Cheadle road and east of the Bunter is shown on the map; but only the southern part of this can be ascertained from evidence at the surface. A section of the seam is seen above the mouth of the railway tunnel, where the hard black band with fossils could be recognised when the cutting was first made. This layer forms a fairly good roof to the workings, but the floor is of the usual soft nature. South of the cutting the outcrop passes under the Bunter, and no reliable evidence could be obtained as to how far south this seam extends; but, as in the case of the Two Yard, the outcrop must turn round somewhere under Huntley Wood, and then trend north; for the proved outcrop of the Yard Coal, under the Bunter, shows that this seam cannot extend far beyond the ridge above the Delphouse pits.

Over this area south of the Cheadle Road much of this coal has been got out. There are patches left, but no plans of these older workings can be found, if they ever existed. North of the fault the coal is thrown down about 20 yards; and, except in the pre-triassic valley referred to below (p. 270), the outcrop under the sandstone must extend further west. But there is good reason to believe that most of the Half Yard Coal has been worked out in this strip. Further north, so far as could be ascertained, only small patches of this coal are left, the bulk of it having been taken out.

Two Yard Coal.—This seam, which is about five feet thick, has been cut through in the siding from the Delphouse Pits to the Cheadle Railway, and from this point it can be traced to the margin of the Bunter on the hill above. Its outcrop under this sandstone was met with in the railway tunnel, and a little further south it must turn round and trend north toward the fault close to the road from Cheadle. Although the beds are thrown down to the north by this fault, the Two Yard Coal does not occur over much of the strip north of the road, as it is cut out by an old pre-triassic valley. It is doubtful if there is any of this coal north of the next east and west fault.

The coal itself, though thick, is of poor quality, and the greater part of it has been worked out. Of the patches left it is probable that much is unworkable owing to their water-logged condition.

The question now arises, how far south do the Yard, the Litley and the Four Foot extend under the red sandstone and marls? As the map shows, the seams lie in a syncline the axis of which trends roughly north and south. This syncline is tilted up towards the south, thus producing a horse-shoe shaped outcrop similar to that of the Dilhorne Coal to the north. If this tilting of the syncline continues toward Tean, as the position of the Huntley, Cobble, and Woodhead seams appear to suggest, then the lower seams of the upper measures cannot extend beyond the south-east end of Huntley Wood. The Coal-measures in this district, however, so often suddenly change their dip that it is possible that these seams may continue further to the south-east, although it is not likely.

CHAPTER XV.

THE TRIASSIC ROCKS.

The Triassic rocks in the south-eastern margin of the Pottery Coalfield rapidly transgress over nearly the entire Coal-measure sequence between Cocknage and Hulme, a distance that is of five miles. Extending eastward, they sweep round the Cheadle Coalfield, along its southern margin, reposing successively between Dilhorne and the Churnet Valley, on the several groups of the Coal-measures. Moreover, between Cheadle and the Churnet they are found filling up an old hollow, excavated and channelled long previous to the advent of the Trias; while unproven by absolute sinking, but obvious from a glance at the geological map, these Triassic rocks fill up an old hollow separating the Cheadle and Pottery coalfields, thus proving almost beyond the possible means of speculation, the original connection of the two Coalfields. The arrangement of the Triassic rocks around the Cheadle Coalfield is very similar to that around the Potteries, and may be conveniently separated into the following sub-divisions in descending order of sequence:—

Keuper.	Red marl. Flags and marls (Waterstones.) Sandstones
Bunter.	Sandstones, more or less pebbly, with massed shingle beds or conglomerate near the top.

Bunter Sandstone and Conglomerate.

This division consists of moderately fine-grained sandstones, with a rather thick, and, over most of the area, persistent bed of conglomerate or masses of pebbles in the upper part. The sandstone itself usually contains some pebbles, but on the whole these are far less numerous here than in the Bunter of the Churnet Valley. This comparative absence of pebbles can be noted in the hill at Cheadle where sections are numerous; and the well sunk in this hill did not pass through a single bed of gravel or conglomerate. The same is true of the sandstone to the east and south of Cheadle, but to the west pebbles are more numerous, and a few small wedges of conglomerate occur about Dilhorne, and also in the hill over the northern mouth of the railway tunnel. Even here, however, the air-shafts showed that the bulk of the rock was comparatively free from stones. These shafts also showed that much of the sandstone is almost white when unweathered, a fact frequently observable at the surface in the Potteries.

The Bunter forms a horse-shoe shaped escarpment facing Cheadle from all points. There is a projection, however, from this escarpment, on the east, where the Bunter fills an old pre-triassic valley, and the end of this projection forms the hill at the foot of which the town stands.

Natural Outcrops.—As already stated, sections of the Bunter are numerous about Cheadle, especially along the high road. On the west side of the horse-shoe shaped outcrop good exposures occur at Dilhorne, and also at the Madgedale Farm. A cutting occurs in the Cheadle road further south, and there is a considerable amount of bare rock in the face of the escarpment over the Delphouse Pits. A cutting occurs on the Uttoxeter road at Huntley, which shows a rather gravelly band, while the rest of the beds are comparatively free from stones, the few that do occur being distinctly small. The beds here slope at about one in fifteen in a southerly direction. It is not easy to say if this is a deposition dip, or the result of slight subsequent movements. Small sections are numerous all along the escarpment further east and north-east, but the downwash greatly obscures much of the hill face in this area. Specially good sections occur on the road to Oakamoor, both ascending the hill and descending it to the Churnet Valley.

The unconformity between the Bunter and the underlying Carboniferous rocks is obvious from the map, but there are two cases in which it is specially interesting. The first of these is connected with the long narrow east and west strip of sandstone on which the town of Cheadle partly stands. The well at the top of the hill is sunk some feet below the level of the stream to the east of the town, yet does not reach the base of the Bunter. Even the cellars of the houses on the north side of the High Street of Cheadle are entirely on the red sandstone; while the Carboniferous rocks are at the surface on the south side of the street. The openings for the town drains showed conclusively there was no fault between the two formations, but that the sandstone clearly lies against the steep side of a pre-triassic valley; the base of the valley being far below the level of the road. This valley slopes in an easterly direction, joining a much larger old valley somewhere about Oakamoor. The sandstone at Cheadle is, therefore, connected with that of the escarpment, and acts as a great water channel, conducting much of the rain that falls on the latter to the bottom of the deep sand-filled hollow at Cheadle, and thus brings an excellent supply of water to the town. The ground about a mile or rather more north-west of Oakamoor, where the base of the Bunter rises and falls repeatedly, also shows the extremely irregular and hilly surface of Carboniferous rocks on which the Bunter rests.

In driving the Cheadle tunnel a curious rock was met with at the base of the Bunter, which is not seen at the surface. It consists of two beds of conglomerate separated by a thin marl

parting. The beds, which are each some 25 feet thick, are composed of sub-angular stones cemented together by a markedly calcareous matrix, and resembles the breccia bands common elsewhere at the base of the Bunter in the Midlands. The calcareous rock evidently thins away before reaching the outcrop facing Cheadle, and is to some extent overlapped by the normal Bunter. In the hedge side, bordering the alluvium at Cecily Mill, to the east of Cheadle, a mass of small angular pebbles may represent the same material with the lime dissolved out of it.

Close to the top of the Bunter, and, so far as is known, restricted to this area, is a curious deposit of massed shingle beds or conglomerate, which is quite unlike the wedges of conglomerate usually so abundant. The latter are essentially discontinuous; while the former, as the map shows, form a continuous deposit over a very large area. The stones in it are the typical Bunter pebbles, and are well-rounded and pitted; but the pitting is not so common. There are thin bands of whitish sandstone in the conglomerate, which though only two or three feet thick are continuous for some distance. In many cases they become stony, the proportion of stones increasing till the bed passes to a conglomerate indistinguishable from the rest of the rock. These massed shingle beds are extensively quarried for road-metal, their principal component being the quartzite, which forms so large a proportion of the Bunter pebbles. This quartzite forms a very good road-metal when not mixed with too large a proportion of softer material. The principal quarries are at Callowhill on the western escarpment; further south on the hill top overlooking the Delphouse Pits; in the by-road that leaves the Uttoxeter Road at Huntley, and on the crest of the hill at every road going in an easterly direction out of Cheadle. There is also a long bare exposure of these gravels at the crest of the Oakamoor Road, which forms a feature in the scenery that can be seen from a great distance to the west.

It will be noted that if we stand on the top of almost any part of the Bunter escarpment these shingle beds keep at almost exactly the same height above sea-level over the whole area. The only exception to this occurs in the by-road referred to near Huntley, where the bed rapidly descends, but whether from a fault, or because it is sloping down into a deep pre-triassic valley that apparently exists further south near Tean, it is difficult to say.

As we recede from the summit of the escarpment in a southerly direction these beds slowly sink, and give the impression that this fall is due to original deposition. As they do so, the sandstone partings appear to thicken at the expense of the shingle or conglomerate.

Above these massed shingle beds is a thin band of sandstone that is rarely well exposed; partly because it is very soft and easily decomposes; partly because if it occurs in a hill-face it is covered with downwash. It would be more convenient to take

the top of the Bunter at the summit of the gravels; but as these are so local it would raise great difficulties in adjacent areas. Immediately above this soft band we reach a more coherent sandstone which is extensively quarried, and this is taken as the base of the next sub-division of the Trias.

Keuper Sandstone and Waterstones.

Above the band of easily decomposing sandstone just referred to there are a series of beds of sandstone of a different nature. The grains of which they are composed are, on the whole, distinctly sharper, and tend to be cemented by iron oxide; while the beds themselves are more coherent, and in consequence are often quarried for building stone. Though comparatively free from pebbles in some parts, they are markedly pebbly as we approach the old pre-triassic land surface in the Oakamoor area; but the pebbles are not nearly so rounded as in the Bunter, and there is good reason to believe that they are rarely, if ever, pitted. The pebbles give the impression of being either Bunter pebbles, eroded under conditions not specially favourable for the production of a markedly rounded form, or else they were derived from the same source as the Bunter pebbles, but under slightly different conditions. The pebbles in both the Keuper and the Bunter are essentially composed of the same material, quartzites being the most abundant.

The Keuper sandstone in this area varies much in different localities, according to its proximity to or distance from the old land surface. In the Oakamoor area the sandstone contains much oxide of iron cement, and numerous pebbles. The latter occur both scattered through the rock and also as thin bands of massed pebbles; which, though rarely more than two feet thick or perhaps less, are very persistent, and cemented together more firmly than the massed pebbles in the Bunter. These features are well seen in the head of Ousal Dale, and again in the hill face due north of this valley where the sandstone is quarried. Another quarry at the same horizon in the sandstone has been opened on the crest of the hill near Threapwood Head, on the opposite side of Dimmings Dale, where the rock is almost free from pebbles, and is a fine-grained compact sandstone, forming an excellent building stone, which the quarrymen assert is the same rock as the Hollington stone. No lines of massed pebbles are seen here; on the contrary the only persistent parting in the sandstone consists of fine red marl. The sandstone round about this district possesses a peculiar mode of weathering, forming knobs or small hillocks that project from the general surface of the ground. This peculiar mode of weathering is probably due to the irregular hardness of the sandstone, and to the removal of the overlying marl which has again exposed the uneven surface. The latter is probably the true cause, as the marl here rests on a very irregular surface of Keuper sandstone. These surfaces can be met

with at intervals as far south-west as Gorstyhill, a little north of Tean.

Both in Dimmings Dale and in the smaller valley that trends south towards Hollington, the Keuper sandstones retain their hardness, and often form bold crags such as are never seen in the Bunter in this particular area. These crags are a well-known feature of Dimmings Dale, and indeed give the character to the Dale. A specially bold crag occurs on the south end of the tongue of sandstone that projects into the marl area south of Alton Common. Pebbles are fairly common, and thin lines of massed pebbles also occur here, but they are not so prominent as in Ousal Dale nearer the old land surface. Further south another conspicuous crag is seen above Lightoaks Farm, where the pebbles are in still smaller quantity. Further west the Keuper sandstone is not recognisable till we reach the ground on the south side of the Cheadle tunnel. Here the beds are usually softer, and contain only minute and scattered pebbles in certain parts of the rock. Much of the stone is white when unweathered, as shown by the material taken from the shaft near the tunnel.

In a number of old marl pits, near the old shaft, to the west of the road to Draycott Cross, soft marly sandstones with marly partings may be noted. These form a kind of passage from the sandstone below to the marl above but are included in the former. No such passage material occurs in the eastern area just described.

Keuper Marls.

These marls are of the same red colour and character as those around the Pottery Coalfield. They are confined to two parts of the present area. The first, which lies between two faults, occurs about Cresswellford and Draycott; the second is shown on the south-eastern edge of the map, south of Alton Common. About Cresswellford the marl contains at times the typical hard thin sandstones (skerries) with casts of crystals of rock salt, and there is a gradual passage downwards into the underlying beds.

The relation of the marl to the Keuper sandstone is different in the area of Alton Common, where there are no passage beds of any importance. Indeed, in this area, near the old pre-triassic land surface, there is a distinct local unconformity between the marl and the underlying sandstone. An excellent example of this unconformity may be seen in an old marl pit, near the farm on the south side of Threap Wood, where a nose of sandstone projects into the horizontal marl. Moreover, small patches of marl are often seen lying between the projecting knobs of sandstone referred to above. On the north-east side of the bold crag, south of Alton Common, the marl appears to be banked against a cliff of Keuper sandstone. The junction at first sight suggests a fault, but no evidence of faulting was found on tracing this junction on the ground.

CHAPTER XVI.

FAULTS.

The general structure of the district has been mentioned on a former page (p. 233). We have now to pass in review the individual faults affecting the strata.

These are of two ages. The oldest and most powerful dislocate the Carboniferous rocks; the later, often on the same line, break the continuity of the Triassic sequence, but their amount of throw and their direction is often a question of some doubt.

Faults in the Carboniferous rocks.

These are numerous, many of which have been proved in the course of mining the coal and ironstone, but cannot be detected at the surface. Those occurring in the ironstone area usually cut the Millstone Grit Series and their position is consequently clear; but over the coalfield it is at times impossible to detect any trace of the dislocations except where they traverse the Woodhead Sandstone. Some of the faults vary rapidly in the amount of throw; others change but little. There is a tendency for these dislocations to occur in groups in one area, while the adjacent district may be comparatively free from faults.

A group of faults occurs in the Ipstones, Froghall and Churnet Valley areas. In the neighbourhood of Ipstones the two parallel faults trending nearly north or south throw in opposite directions, and let down a long strip of Coal-measures between the Millstone Grits. About the middle of the deep hollow both of these faults must have a throw of more than 200 feet, but further south the throw slowly diminishes till at length they appear to die out. The fault trending north-west and south-east from Belmont Hall towards Froghall is well shown at the surface. Close to the hall it throws the First Grit against the Third, while in the lane south of Booth, the First Grit is brought against the Crabtree Coal, in which a small opening has been made. In the Churnet Valley the ironstone is much below the level of the river bed while on the opposite side of the dislocation it is on top of the hill. The fault west of Pettyfields was proved in mining, but its further course is clearly marked by the displacement of the Woodhead and Rider coals, which are thrown down to the east about 150 feet.

The fault on the west side of the First Grit about Belmont Hall is shown by the workings of the Crabtree Coal and gannister in Coalpit Wood. These rocks are about 120 feet above the grit, but the fault has thrown them down to the west till they are considerably below the base of that rock.

In the Consall Hall area the master fault trends north-north-east and attains its maximum effect close to the Hall, where it must throw down to the west more than 200 feet, but from this point it diminishes in both directions.

About Wetley Rocks the beds are greatly disturbed and often on end. This disturbance seems connected with a fault that near Highfields throws the First Grit down to the west against the Third; quite at the edge of the map it throws the Coal-measures against the middle of the same grit. It cannot here have a less throw than 300 feet, and must penetrate some distance into the Pottery Coalfield. No coals are being worked in this neighbourhood, and nothing is known further about this dislocation; it is a pre-triassic fault and does not affect the Bunter sandstone by which it is covered farther to the south-west.

There are several faults in the neighbourhood of Bank Top, one of which, trending east and west, is well shown at the surface by the outcrop of the Rider and Woodhead Coals. At the stream north-west of Dairy House it has a downthrow to the north of about 150 feet. Further east it appears to break up into a number of small dislocations which were proved in the older workings at Hazlewall Colliery.

Numerous faults have been proved in the coal workings, of which no trace can be found at the surface till they cut the outcrop of the Woodhead Sandstone, when their further course is usually clear. A typical example of such a fault is shown a little west of Hazlewall Pit. West of Parkhall Shaft a fault was proved not only in the colliery, but in some shallow workings in the Four Foot Coal at Parkhall Farm, and again at the old pits near the disused brass works west of Cheadle. It was exposed in the cutting at the entrance to the Cheadle tunnel, and repeats the outcrop of the Yard Coal, throwing down to the east some 30 feet. This fault has a singularly uniform throw throughout its whole length, yet only in this artificial section is there any evidence at the surface to suggest a fault.

The set of east and west faults in the Dilhorne and Cheadle district are in the main proved only from mining evidence. The most important of these is the fault at Dilhorne. This throws down to the south and brings on the highest beds of the area, conveniently called the Delphouse Series, (Upper Pale Group). Shafts on the north side were sunk to the Dilhorne Coal, passing through a small seam above it. Close to the south side of the fault shafts were sunk to the Litley, and also apparently to the Four Foot Seam, though there seems some dispute about the latter. The exact throw in the Dilhorne area is thus a matter of doubt. But just under the extreme north-west end of the Bunter near Cheadle, a level, starting in the Woodhead Coal, was driven through the fault till the Rider Seam was cut, showing the fault here

had a downthrow to the south of somewhat over 120 feet. This level is of great importance, for it shows conclusively that the Dilhorne Coal is thrown *down* to the south, and is below the Delphouse coals. It cannot possibly be at the top of these beds as is generally supposed.

A fault throwing down to the south-west about 90 feet was proved in the Birches Colliery, near Cheadle. It trends north-west and south-east, and was met with a little to the south-west of the shaft.

About Oakamoor there are a number of faults, some of which have a considerable throw. The clearest is the one at the foot of the First Grit escarpment, near Crowtrees and Moneystone. Here the coal of the Third Grit is on a level with the base of the First Grit, implying a downthrow of about 100 feet to the west; further north it increases somewhat, for the two grits occur side by side. There seems to be a network of faults about Oakamoor station; one of these is well shown by the outcrop of the two grits on the south side of the tunnel.

Faults in the Triassic rocks.

While most of the faults described above are of pre-triassic age, there are some faults in the district that cut the Trias. Two of these are shown in the Draycott area. They throw in opposite directions, causing the Keuper marls and sandstones to lie in a trough between the two outcrops of Bunter. If the evidence obtained from the old shaft near the tunnel can be relied on, the more northerly of these faults must have a throw of at least 300 feet, but that of the more southerly is considerably less.

In the south-eastern part of the area there appears to be a fault of considerable throw between the Bunter and Keuper sandstones; but the amount is difficult to ascertain as it seems possible that the Keuper sandstone may here lie in an eroded hollow of the Bunter. Several small faults may be seen in the roadside on the face of the Bunter escarpment, but they have no structural importance. A fault of 15 feet throw occurs in the quarry in the Keuper sandstone on the north side of the Cheadle and Alton Road. It cuts the sandstone in a peculiarly clean manner, and does not easily catch the eye. This seems to be rather a feature of the smaller faults in the Triassic rocks.

CHAPTER XVII.

SUPERFICIAL DEPOSITS.

Glacial Drift (Boulder Clay).—The distribution of the Boulder-clay, or true Glacial-drift, will be best understood by the statement that all but the margins of the Cheadle table-land are now practically free from this deposit. To the north-west of the area true Boulder-clay occurs, and this forms the taper end of the great sheet of Drift that extends from the Cheshire Plain. About the head of the Consall Valley this Drift is not thick enough to map, but north of the village it gradually thickens, though even here the outcrop of the grits is clear. Still further north, about Parkhouse, the Drift is thick enough to completely obscure the western outcrop of the Third Grit. Foreign boulders are fairly abundant in the Drift here, the more common being fragments of Eskdale and Ennerdale granite, and the ash-rocks of the Lake District. Of the smaller pebbles by far the most common are the greenish greywacke, which probably comes from the southern part of the same district; but their origin has not been satisfactorily traced. The boulders may be examined in a little disused brick-pit close to the Consall Village road, and about quarter of a mile east of Wetley Rocks. On the edge of the by-road to Folly and Park House farms, to the north of the pit just referred to, a small heap of fragments of these Lake District rocks gives an excellent sample of the more abundant types of these foreign boulders.

A very small patch of typical Boulder-clay occurs to the west of Dilhorne, on the extreme edge of the area here described. It forms a part of a small isolated deposit of Drift that has been banked up against the east side of the hill of Bunter sandstone. At the edge of the map, at Forsbrook, another small patch of this material occurs, which is also the edge of a large mass of Drift to the west.

Doubtful Drift Deposits.—Bunter pebbles occur more or less abundantly over the whole of the area described; but it is doubtful whether these pebbles should be claimed as a true glacial deposit, or are merely the stones left after the clay matrix had been washed away.

Every gradation is met with, from isolated pebbles which would almost escape notice but for artificial openings, to a deposit at times three feet thick composed of clay crowded with Bunter pebbles, but containing no far-travelled rock fragments. The view that they are simply a remnant of the Bunter, that once undoubtedly covered the whole area, seems very unlikely when

their position is noted, for in some cases these pebbles occur on the Keuper sandstone which contains no such well-rounded pebbles. They must, in such cases, have been distinctly lifted up to some extent in order to occupy the position in which they are now found.

A kind of connecting link between this wash-like stony material and the more normal Boulder-clay occurs in the long hollow through which the by-road passes from Dairy House to the farm north of Bank Top, in the north-western part of this area. The deposit seems to continue for some distance down the main valley keeping on the west side of the stream, and to merge into the typical "wash" so abundant in this district at the foot of long slopes. Bunter pebbles are abundant in the higher part of the deposit about the road, but they appear to decrease steadily close to the stream. Whether this material is a true glacial Drift or not is uncertain. It is difficult to believe, however, that it is not in some way connected with the breach or hollow in the outcrop of the grit that occurs at the fault shown on map. It is possible that either the ice sent a small tongue through here, or more likely that a small sub-glacial stream carried the material through this hollow which formed the only means of egress for the water.

Another small area, where these pebbles are present in great numbers, occurs on the west side of the stream above the Cheadle Gas Works.

On top of the Bunter table-land, here and there, are small patches of clay material containing pebbles, many of which lie with their longer axes vertical. These deposits are not usually more than a foot or two thick, and can rarely be detected unless exposed in some artificial opening. Two instances of this material may be noted, one at Callowhill, south of Dilhorne; the other at the small pit at Rakeway Head, south-east of Cheadle. A little south of the last pit there seems to be a similar deposit of clay on the rising ground at Cheadle Common; but there are no good openings in this.

On the Keuper sandstones to the north of the Alton Road, well-rounded pebbles occur scattered over the surface of the ground. These have undoubtedly come from the Bunter, for no such pebbles occur so high up in the Triassic rocks as this.

A possible explanation of the phenomenon of the occurrence of these Bunter pebbles unaccompanied by any far-travelled boulders is that they were collected from the Bunter on the immediate margin of this area (west and north-west) and were entangled in the upper layers of the ice sheet, while the far-travelled boulders were buried at lower levels in the ice. On reaching the margin of the table-land, owing possibly to the waning strength of the movement of the ice, only the upper layers containing the locally-collected Bunter pebbles, were driven over the table-land as a whole. In a few places on its north-west margin, however, the lower layers were forced over the edge

of the higher ground, and here alone the foreign boulders are found.

Area East of the Churnet.—To the east of the Churnet, the distribution of Millstone Grit boulders seems to show clearly that the whole district was once covered by a moving ice sheet capable of transporting large blocks of stone considerable distances. In this district many of the walls of the fields are built of blocks of the First and Third Grits. These are often a considerable distance from any outcrop of these rocks, and the shape of the stones in the walls is conclusive that they are broken up loose blocks, and have not been obtained from a quarry. A little consideration of the amount of material required shows how numerous these blocks of grit must have been before the fields were cleared. Such blocks are still numerous in the beds of the small streams from which, on account of their weight, it did not pay to lift them. The most conclusive evidence that these grit blocks are really a form of glacial Drift was shown in quarrying the fireclay below the Crabtree Coal close to the small stream below the little lane at the south end of Ipstones. Here the sloping surface of the rock in the bank-side is covered with a curious clay containing large blocks of grit, though these are not so well rounded as one would have expected. This deposit is overlain by wash, several feet thick in some places, with no grit boulders in it. The grit-bearing clay is thus older than the wash, and as the grit blocks have travelled some distance, the deposit is probably a true Boulder-clay. There is, however, no deposit of similar clay on the flatter ground above the hollow in which the stream runs, the grit blocks alone being met with.

Patches of clay with Bunter pebbles occur here and there in the gently-sloping hollow between the old Whiston Works and Shirley Common, and though here and there it is fairly easy to define the limits of this material, in many places it was impossible to do so, for it tails away till it is either too thin to map or disappears altogether. A small pit in this clay occurs close to the high road to the north-east of the works; while a much larger one is seen on Shirley Common where the Whiston Road crosses the Caldon Low Tramway. Part of this latter clay rests on a grit, below the Third Grit, and from its position and composition can scarcely be of the nature of wash. Indeed it is difficult to see how this can be anything else than true glacial Drift. This, as noted above, leads to the conclusion that the Bunter pebbles scattered over the entire country are the remains of glacial Drift from which all the softer clay matrix has been washed away.

Rain Wash.—Any one familiar with the north of England or Scotland can scarcely fail to be struck with the amount of wash or material that has been accumulated in this area at the foot of slopes, even when these are at a comparatively low

angle. Though this material is present in the more northerly districts, it does not attain anything like the thickness observed in this part of Staffordshire. It is derived from the soft shales and the Drift, but especially from the Bunter, in which latter case it obscures the base of that sandstone. It also causes at times a difficulty in fixing the limit of the alluvium, for the very fine material of which it is composed is washed down over the edge of the equally fine alluvium, and conceals the true junction of this with the rock slope or Drift. It strongly suggests that the glaciation of this area must have ceased, and more modern conditions of denudation begun much earlier than in Northumberland and Scotland. As the remarks on the doubtful Drift show, this wash often bears a very close resemblance to the clay in which the Bunter pebbles occur; in most cases it is this resemblance that raises the doubt whether the stony clay is true Drift or not.

Alluvium.—Only in the bottom of the Churnet Valley does the alluvium attain any size. Even in the case of the Churnet, where the river flows through the gorge-like hollow north of Consall Forge, the alluvium is almost too narrow to map; and farther south as far as Froghall, it is still narrow as a rule. To the south of Froghall and to the north of the gorge, it attains some considerable breadth. This is due to the rocks of the valley being softer, and in consequence a deeper and broader hollow has been eroded. In addition the material of this alluvium is a very fine watertight silt, and essentially of the nature of a material filling up a hollow, rather than the usual sand and gravel seen where a river is eroding its base. This is specially noticeable in the case of the northern area, where the Churnet has silted up what is practically a long lake-like hollow extending far to the north past Cheddleton, Leek, and Rudyard.

In its passage through the gorge the Churnet has formed a few very narrow river-terraces, but these strips have been so much interfered with in making the canal and the railway that they are now scarcely traceable.

CHAPTER XVIII.

WATER SUPPLY.

Triassic Water Supply.—The town of Cheadle is supplied with water obtained from a well sunk through the Bunter sandstone forming the rising ground at Cheadle. The well is sixty-five yards deep, and the base of it is some yards below the bed of the stream at Cecily Silk Mill, which lies a little east of the town. The well does not reach the base of the Bunter, which fills an old pre-triassic steep-sided valley. This valley has been proved to continue to the east, and the rock that forms Cheadle Hill is continuous with the main mass to the south-east. This narrow valley filled with porous sandstone acts as a great water channel carrying a considerable portion of the rainfall on the Bunter escarpment area to the base of the well at Cheadle. In order to test the amount of water available the pumps were worked continously for fourteen days, pumping at the rate of 120 gallons a minute, without lowering the surface of the water more than about two feet.

Immediately south of the Cheadle Railway Tunnel the Bunter lies at some distance below the surface, being let down by the two trough faults which are shown on the map. Not far from the tunnel a shaft was put down in search of coal, but the quantity of water met with was so great that after passing through the Keuper sandstone, a few yards only of the Bunter was pierced before the work had to be abandoned. For a considerable distance from this shaft, both in a north-western and south-eastern direction, between the two trough faults, a large quantity of water could be obtained, especially near Tean, where there are indications of a locally deeper pre-triassic valley.

Near the face of the horse-shoe shaped escarpment of the Bunter not much water is usually met with, because the surface of the underlying Carboniferous rocks generally slopes away from the escarpment, but farther away from this the amount of water will of course steadily increase.

As might be expected, strong springs issue from the Bunter, where the base of this rock descends to the bottom of the Churnet Valley, as about Oakamoor and further to the north-west about Eastwell. About Alton, the base of the Triassic rocks must be far below the level of the river, and an abundant water supply must be available; but some recent trials suggest that, as the Trias in this area is largely capped with red marl, the water may contain much sulphate of lime, and be unduly hard.

Millstone Grit Supply.—The old shafts sunk in the neighbourhood of Ipstones proved the presence of large quantities of

water in these grits, especially the Third. These grits slope down toward Froghall in the Churnet Valley. A shaft or boring put down in the vicinity of the bridge, or anywhere between the two parallel faults bounding the Ipstones Valley, would tap a large volume of water which would probably rise to the surface, as there must be a strong head of it owing to the height of the gathering ground above Froghall. The First Grit has a large exposed outcrop to the north and east of Whiston, so that a copious supply could be tapped in the Churnet Valley by a shaft or borehole put down due south of Dustystile. There is no doubt that the water would rise to the surface here, for a borehole at least fifty feet above the river and close to the little stream on the east side of Woodhead House was put down to this grit, from which the water has poured out at the surface for years without intermission.

About Consall Forge and Consall Valley, to the west, similar good sites can be selected for obtaining water from these grits, for there must be a large amount banked up against the west side of the long fault trending north-north-east which passes close to Consall New Hall.

The faulted nature of the country greatly aids at times in the circulation of underground water, and an excellent illustration of this occurs to the north-north-east of Foxt. The Third Grit is faulted against one of the lower grits which here begin to assume importance in this series. A boring sunk close to the fault taps not only the water of the thinner and lower grit, but also that from the far thicker Third Grit which is faulted against the smaller bed. The quantity of water thus brought into the boring is so great that it overflows at the surface, and has been taken to supply the village of Kingsley, on the opposite side of the Churnet Valley.

Supply from the Coal-measure Sandstones.—Broadly speaking, water does not circulate freely in these rocks, and the amount available is often not more than sufficient to supply the needs of a house or farm. Indeed the Woodhead Sandstone is the only bed from which any appreciable amount can be obtained. This so often forms the surface rock of the Churnet Valley that a considerable part of the rainfall that sinks into it escapes at the base of this long outcrop, giving rise to the landslips, previously referred to, in the shales of the lowest Coal-measures.

A list of fossils and a palæontological account of the Cheadle Coalfield has been prepared by Mr. John Ward, but unfortunately arrived too late for insertion in this Memoir. The list includes many interesting fossils collected from the new sinking of the Wonder Pit (p. 265) and other shaft sinkings. We hope Mr. Ward will shortly publish his results.

CHAPTER XIX.

GOLDSITCH MOSS COALFIELD.*

This model example of an infolded syncline of Coal-measures is beyond the limits of the resurvey; but since it lies within the North Staffordshire District and remains to-day, as regards its coal-workings, very much as it appeared in 1866, we reprint, in order to complete the description of the district, extracts from the published account of Green & Hull.†

The Pottery Coalfield as we have seen is a deep infold of the Coal-measure strata; the Shaffalong Coalfield is a much shallower fold; that of the Cheadle Coalfield presents a shallow but wider syncline of greater importance than that of Shaffalong, but of less degree than the Pottery deep infold. The basin of the Goldsitch Moss may be compared in importance to that of Shaffalong. In each only the lowest and least important Coal-measure strata are involved, and in each the amount of coal available has proved of insignificant quantity when compared with that obtained or still obtainable in the Pottery and Cheadle areas.

Surrounded in perfect symmetry by the First and Third Grits this small basin contains the following rock sequence:

GOLDSITCH MOSS COALFIELD.†

	Ft.	in.		Ft.	in.
Coarse Red Rock					
Shales					
Coal, *Silver Seam*	1	4	to	1	6
Measures	130	0		–	–
Coal, *Thin Seam*	1	4	,,	1	6
Measures - -	45	0	,,	60	0
Coal, *Thick Seam* -	2	0	,,	2	3
Measures -	60	0	,,	72	0
Coal, *Cannel Seam* - -	–	6	,,	2	0
Shales - - - - - - - -	9	0	,,	12	0
Coal, *Bassy*, black shale with thin layers of coal	5	0	,,	6	0
Sandstone, *Woodhead Hill Rock* -	57	0		–	–
Black shales, Ironstone and Flags	267	0		–	–
Coal, *Feather-edge Coal*	4	0	,,	6	0

Little more is known of the sequence to-day. In his description of the ground Green remarks that, "The beds lie with the most perfect regularity in the form of a long trough broken off on the north by the Crag and Gradbatch Fault. On each side of the central valley which is occupied by Lower Coal-measures

* The Geology of the Country round Stockport, Macclesfield, Congleton, and Leek, *Mem. Geol. Survey*, 1866. The above account is excerpted by W. Gibson.

† This account is drawn up from information supplied by old colliers. Loc. cit., p. 26.

the massive gritstones slope up the hillsides in broad sheets of heather-clad rock, ending at top in rugged crags, with the broken ends of the beds sticking boldly out into the air. The synclinal arrangement of the strata is thus shown as clearly as in a model, and perhaps it would be difficult to find a place where the shape of the ground points out so unmistakeably the geological structure of the country."*

* Short lists of the fossils obtained from this coalfield are given by Mr. John Ward (*Trans. North Staff. Inst. Min. and Mec. Eng.*, vol. x., 1890).

PART III.

PALÆONTOLOGY OF THE POTTERY COALFIELD.

By JOHN WARD, F.G.S.

CHAPTER XX.

Introduction.—No coalfield in Great Britain, of equal size, possesses a richer and more varied series of organic remains than that of the Potteries.

For many years this coalfield has been the object of detailed investigation by a small band of local observers who have determined the stratigraphical position, geographical distribution, and palæontological horizons which characterize the several subdivisions into which the local development of the Coal-measures has been divided. As a result of these researches, a large assemblage of fossil remains belonging to both the flora and fauna have been collected and described.

The Pottery Coalfield has long been recognised as an unrivalled field for the study of Carboniferous fishes. Notwithstanding the numerous and varied series of molluscan remains it has yielded, and the equally abundant flora, it is the richness of its fossil fish-fauna that has given it a special interest to the student of Palæozoic ichthyology.

The fossil fishes alone comprise thirty genera and upwards of fifty species; and of these, the types of six genera and twenty-six species have been derived from this district.

It is worthy of note that the vertebrate fauna of the Coal-measures of the district has occupied the attention of some of the most eminent authorities of fossil ichthyology. We recall the names of Agassiz, Egerton, Huxley, Traquair, Young, and Davis, whose writings have contributed so largely to the knowledge of the animal life of the Coal-measure period.

History of Previous Research.—The first recorded discovery of organic remains in the Coal-measures of the Pottery Coalfield dates as far back as the year 1835, when Sir Philip Egerton read a paper before the Geological Society of London, "On the Discovery of *Ichthyolites* in the south-western portion of the North Staffordshire Coalfield."* The fossils enumerated included,

* *Proc. Geol. Soc.*, vol. ii., p. 202.

among other forms, a small *Palæoniscid* fish from the Coal-shales of Silverdale, near Newcastle-under-Lyme. This specimen was subsequently submitted to Professor Agassiz and by him named, but not described, under the title of *Palæoniscus Egertoni.** Other remains of fishes new to science were submitted to Professor Agassiz, including several forms of teeth from the same locality, upon which were founded the genera *Diplodus*† *Ctenoptychius*,‡ and *Helodus*.§

In 1844 the "*Natural History of the County of Stafford*" was published by Dr. R. Garner. This work contains a *résumé* of the Geology and Natural History of Staffordshire. It is accompanied by several plates containing figures of fossils; a portion of plate "E," being devoted to figures of shells and fish teeth from the Coal-measures of this district, but no specific names are given. The list of fossils given in the first edition was considerably enlarged in a supplement published in 1860.

The first detailed description of the distribution of the fossils of the coalfield was given in 1859, in a joint paper by Messrs. Garner and Molyneux "On the Coal Strata of North Staffordshire with reference particularly to their Organic Remains," and read before the Geological Section of the British Association at Aberdeen.

In 1860, a paper, an abstract of which is given in *Reports Brit. Assoc.* for 1860 (Sections, p. 88), was read at a meeting of the British Association by W. Molyneux, entitled, "Remarks on Fossil Fish from the North Staffordshire Coalfield."

In 1862, the first collective list of the fossil Mollusca of the Coal-measures of North Staffordshire appeared. The list was drawn up by J. W. Salter, from an examination of a large series of Molluscan remains submitted by the present writer for determination. This list was subsequently published as an Appendix to the "*Iron Ores of Great Britain*," Part iv. (*Mem. Geol. Survey*).

In the same year, T. Wardle (afterwards knighted) contributed a chapter to Mr. John Sleigh's "Ancient History of Leek," on "The Geology of the Neighbourhood of Leek." In this, a brief description is given of the different groups of strata of the district. He further reproduced Salter's list of Coal-measure Mollusca, with some additional species, at the same time adding a comprehensive list of the fauna of the Carboniferous Limestone of North Staffordshire. The work is illustrated with four plates with figures of fossils from the Carboniferous Limestone, Millstone Grit, and Coal-measures of the adjoining district.

In 1863, at a meeting of the British Association at Newcastle-on-Tyne, a committee was appointed, consisting of Sir Philip Egerton, and Professor Huxley, with W. Molyneux, Reporter, to draw up and report on "The Distribution of the Organic

* *Poissons Fossiles*, vol. ii., p. 302.
† Agassiz. *Poissons Fossiles*, Tome iii., p. 204.
‡ *Ibid.*, Pl. xix., fig. 1.
§ *Ibid.*, Pl. xix., figs. 8–10.

Remains of the North Staffordshire Coalfield." (*Report Brit. Assoc.* for 1864, pp. 342–344.) In the following year (1865), the Committee presented a further Report, which contained much valuable information relating to the distribution of the organic remains. To this Report (pp. 317–320) there is an Appendix by Dr. J. Young "On the Distribution of the Vertebrate Remains from the North Staffordshire Coalfield."

In 1864, a paper was read at a meeting of the Dudley and Midland Geological Society on "The Distribution of the Organic Remains of the North Staffordshire Coalfield."

In 1866, Sir Philip Egerton communicated to the *Geological Society* of London, a paper "On a new species of *Acanthodes* (*A. Wardi*) from the Coal-shale of Longton."† In this he further alluded to certain fragmentary remains of a larger species of *Acanthodes* from the Knowles Ironstone, Fenton, submitted to him for examination by the present writer, but did not distinguish it specifically. The same volume (p. 301), contains an important Paper "On the Affinities of *Platysomus* and allied Genera," by Dr. J. Young. In this the author discussed the affinities of the *Platysomidæ* which he considered to be distinct from, although possessing affinities to the *Pyconodontidæ* previously proposed by Egerton to include *Platysomus*, and approved by Agassiz and other authorities. Dr. Young therefore proposed a new sub-order "*Lepidopleuridæ*" for inclusion among other forms of the above-named genus. He further described in detail, and figured, the structural characters of *Amphicentrum granulosum*, and another new genus, *Mesolepis*, of which two species were described *M. Wardi* and *M. scalaris*, from the Knowles Ironstone, Fenton.

In 1866, Professor Huxley contributed to the *Twelfth Decade of the Memoirs of the Geological Survey* an important Memoir in which, among other genera of Fishes, he described the structural characters and affinities of the genus *Cœlacanthus*, Agass. largely based upon specimens from the Coal-measures of North Staffordshire.

In 1866, Dr. Young further contributed to palæontological literature a paper on Carboniferous Glyptodipterines.‡ In this communication the author described, among other remains, a new genus of fossil fishes having "large quadrangular scales with rounded angles." For these he proposed, provisionally, the generic title of *Rhomboptychius*, basing his diagnosis of characters largely upon specimens obtained from the shales overlying the Knowles and Deep Mine Ironstone, Fenton, but did not distinguish it specifically. More recent researches have shown that *Rhomboptychius* cannot be generically separated from the genus *Megalichthys*,

* J. Ward, *Trans. Dudley and Midland Geol. Soc.*, vol. ii., p. 21.
† *Quart. Jour. Geol. Soc.*, vol. xxii., p. 468.
‡ *Quart. Journ Geol. Soc.*, vol. xxii. (1866), pp. 596–598.

Agass., to which genus Dr. A. S. Woodward, in his British Museum "Catalogue of Fossil Fishes" (vol. ii., p. 384), has relegated it under the title of *Megalichthys intermedius.**

In 1870, the writer read a paper at a meeting of the *North Staffs. Nat. Field Club* (*Report* for 1870, p. 28), entitled "Notes on Fossil Trees in Messrs. Hampton's Marl-Pit, at Joiner's Square, Hanley;" and in the same year further contributed to the *Transactions of the Midland Scientific Society* (part ii. (1870), p. 1), a paper "On the Fossil Fishes of the North Staffordshire Coalfield," in which the whole of the fossil fish-fauna then known to occur in the Coal-measures of the area in question were enumerated.

In 1871, a valuable paper was published in the *Annals and Mag. Nat. History* (ser. 4), vol. vii., pl. vi., p. 73, entitled "Description of a Considerable Portion of a Mandibular Ramus of *Anthracosaurus Russelli*, Hux.," by Messrs. Hancock and Atthey. The description was based upon a unique specimen derived from the New Ironstone (= Rag Mine Ironstone), Fenton.

In 1874, a paper by Dr. Traquair appeared in the *Geological Magazine* (vol. i. (2), pl. xii., p. 241), which gives a detailed description of the structural peculiarities of a rare species of fossil fishes (*Cycloptychius, carbonarius*, Hux.) from the Deep Mine Ironstone, Longton. The type specimen of the genus was derived from the same bed and locality. The description is accompanied by a beautifully executed illustration of the fish referred to, here figured for the first time, together with an outline sketch illustrating the osteology of the head.

In the following year (1875), Dr. Traquair further contributed to fossil ichthyological literature a paper to the *Annals and Mag. Nat. Hist.* (vol. xvi. (4) p. 273), "On the Structure of *Amphicentrum granulosum*, Young." In this communication he described in detail the principal characters of this species, special attention being directed to the osteology of the cranium and dentary apparatus. In 1878, however, he pointed out that, on examining the original specimen of a small dental plate in the Woodwardian Museum at Cambridge, described by M'Coy in 1848, by the title of *Cheirodus pes-ranæ* (*Annals and Mag. Nat. Hist.* (5) vol. ii., p. 17), that it was in reality identical with the mandibular dental plate of Young's genus *Amphicentrum.*† He therefore proposed to abolish the generic term "*Amphicentrum*," Young, and to substitute M'Coy's *Cheirodus* as having priority, but retaining the specific title of "*granulosus*."

In a report submitted to the Belfast meeting of the British Association in 1874, by Prof. L. C. Miall, "On the Structure and Classification of the Labyrinthodonts," reference was made to a specimen of a small Labyrinthodont (*Keraterpeton Galvani*, Hux.) (here referred to the genus *Urocordylus*, Hux.) obtained

* "Catalogue of Fossil Fishes in the British Museum," vol. ii., p. 384.

† *Annals and Mag. Nat. Hist.*, Ser. 5, Vol. 11, p. 16.

from the shale associated with a thin band of ironstone overlying the Ash, or Rowhurst Coal (Longton Hall Colliery, Longton).

In 1875, the *North Staff. Nat. Field Club* reproduced a series of Papers and Presidential Addresses delivered before the Society.* Among others the present writer contributed one "On the Organic Remains of the Coal-measures of North Staffordshire, their Range and Distribution, with a Catalogue of the Fossils and their mode of Occurrence," and another on "Notes on the Fossil Trees in a Marl-Pit at Hanley."

A valuable monograph was contributed by Dr. Traquair to the *Palæontographical Society* (vol. for 1877), on "The Ganoid Fishes of the British Carboniferous Formation," part i., *Palæoniscidæ.* Besides a detailed description of the structural characters of the Ganoidei, it contains a geological and zoological introduction, and also treats of three new species of Palæoniscid fishes. It is illustrated by beautifully executed plates with figures of the specimens described in the text. The author draws attention to the affinities existing between the living *Acipenseroidei* and the extinct *Palæoniscidæ.*

In 1878, Dr. Traquair (*Trans. Roy. Phys. Soc. Edinburgh* (1878), vol. iv. pp. 239–241) described the specific characters of two new species of fossil fishes, viz., *Rhadinichthys monensis* and *R. Wardi.* The genus *Rhadinichthys* being instituted by him for the inclusion of fishes "approximating in certain points to *Palæoniscus ornatissimus*, Agass."

In 1877, Dr. Traquair in an exhaustive paper (*Trans. Roy. Soc. Edinb.*, vol. xxx., 1881, p. 169), gave an account of the cranial osteology of *Rhizodopsis sauroides*, Will., his diagnosis of the species being based principally upon materials obtained from North Staffordshire. Another, and still more valuable paper by the same author, was contributed to the above Society (vol. xxix., 1879, pp. 343–391, pls. iii.–vi.), "On the Structure and Affinities of the *Platysomidæ*." In this memoir the author discusses the "History," "Geological Distribution," and "Structure" of each genus of Platysomid fishes. Reasons are given for allying the *Platysomidæ* with the *Palæoniscidæ* and not with the *Pycnodontidæ*, as originally proposed by Dr. Young in the paper previously referred to. The structural characters of several of the genera described were chiefly founded upon an examination and study of a large suite of specimens, submitted by the present writer, and obtained from this district. The memoir is illustrated with four finely executed plates, containing upwards of sixty figures.

In 1880, a new species of *Pleuracanthus* (*P. Wardi*) from the New Ironstone, Fenton, was described by J. W. Davis.†

* Addresses and Papers, Hanley, 1875.

† *Quart. Jour. Geol. Soc.*, vol. xxxvi. (1880), p. 334, pl. xii. Fig. 6.

The next record from the district appears in the *Geological Magazine* for 1886 (Dec. iii. Vol. iii. p. 441) in which Dr. Traquair describes a new species of the genus *Elonichthys* (*E. microlepidotus*) and one of the genus *Rhadinichthys* (*R. macrodon*), from the Knowles Ironstone, Fenton. The same Journal for 1888 (vol. v., p. 253), contains a further description of new species of Palæoniscid fishes namely: *Rhadinichthys Planti* and *Gonatodus Molyneuxi*, both obtained from the Deep Mine Ironstone, Longton.

In 1890, the present writer contributed a paper to the *North Staffs. Inst. Mining Engineers* (vol. x., pp. 1–189) which contains an account of what was then known relating to the principal geological features, and the fossil flora and fauna of the Coal-measures of North Staffordshire. It is illustrated with nine plates, containing figures of the typical forms of Mollusca, Fishes, and Amphibia.

In 1891, the fossil flora of the district was described in detail by Mr. R. Kidston in a paper on "The Fossil Flora of the Coalfields of the Potteries."* He enumerates no less than thirty genera and sixty species of fossil plants, determined from specimens submitted by Dr. Hind, Mr. F. Barke, and the writer.

Dr. A. S. Woodward's "Catalogue of the Fossil Fishes in the British Museum" (Natural History, 4 vols. 1889–1901), although not directly devoted to the Palæontology of the district may be here noted, as it includes various species of fossil fishes from the Coal-measures of North Staffordshire contained in that museum.

In an important Monograph published in the *Transactions of the Royal Dublin Society* (Vol. iv. (2) pp. 703–748), by J. W. Davis, on "The Fossil-Fish Remains of the Coal-measures of the British Islands," the author describes and figures a number of Selachian fin-spines of the genus *Pleuracanthus*. Among them were several remarkably fine examples of *Pleuracanthus* (*Orthacanthus*) *cylindricus*, upwards of eighteen inches in length, from the New Ironstone (= Rag Mine) and Knowles Ironstone, Fenton.

The Molluscan fauna of the Carboniferous rocks in general, which for a long period has been greatly neglected, has been taken up with great enthusiasm by Dr. Wheelton Hind. In 1893 he contributed a paper to the Geological Society of London, "On the Affinities of *Anthracoptera* and *Anthracomya*, the generic characters of each of these genera are described, and detailed descriptions and figures of the then known species, together with new forms, are given.

The same author contributed to the *North Staffordshire Nat. Field Club* ("*Trans. North Staffs. Nat. Field Club*," vol. xxvii., part i., p. 103), a paper on "Additions to the

* *Trans. Roy. Soc. Edinburgh*, vol. xxxvi., Part i. (No. 25), p. 63.

Palæontology of North Staffordshire." In this paper the features exhibited in several genera of Mollusca obtained from the area are described and of several new species an account is added, together with four plates illustrating these fossils. The same "Transactions" (page 67), contains a paper by the present writer giving a brief historical account of the rise and progress of palæontological research in North Staffordshire, from the date of the earliest recorded occurrence of fossil remains in the year 1835 to the time of writing.

In 1894, an important contribution to the palæontology of the coalfield was given by J. W. Davis in the *Trans. of the Royal Dublin Society* (part iii., vol. v. (ser. 2) pls. xxvii.–xxix.). in which he describes in detail the structural characters of a unique series of specimens of *Acanthodes Wardi*, derived from the shales of the Deep Mine Ironstone, Longton. In addition he describes and figures (ibid., pl. xxix., figs. 5, 6) remains of a large Acanthodian fish under the title of *Acanthodes major* obtained from the Knowles Ironstone, Fenton. The specimens upon which the specific name was founded were those previously alluded to by Sir Philip Egerton at a meeting of the Geological Society of London in 1864.*

In the same year Part I. of a Monograph on Carboniferous Lamellibranchiata was contributed to the Palæontographical Society by Dr. Wheelton Hind; it is devoted to the genus *Carbonicola* (*Anthracosia*), and embraces all the known species of the genus. A *résumé* of the views held by previous authors on the genus is also given. The descriptions, accompanied by eleven plates of figures of the fossils illustrating the forms described in the text, were largely based on the examination of specimens collected from the Pottery Coalfield.

In this year, Dr. Traquair published, in the "*Ann. and Mag. Nat. Hist.*" (Vol. xiv. (1894) p. 372), a paper entitled "Notes on Palæozoic Fishes," No. 1, in which he described two new species of fossil fishes (*Acanthodopsis microdon* and *Eurylepis anglica*) the first from the Knowles Ironstone and the second from the Deep Mine Ironstone, Longton and Fenton.

In 1895, Dr. C. W. Andrews contributed a short but interesting paper to the *Geological Magazine* (vol. ii., ser. 4, p. 81) "Note on a specimen of *Keraterpeton Galvani*, Hux., from shale associated with the Ash Coal, Longton." The paper fully describes the structural characters exhibited by the specimen and is illustrated by a woodcut.

In the same year, Dr. Wheelton Hind published Part II. of his Monograph of the Carboniferous Lamellibranchiata. In this he describes, and figures, a number of species of the genera *Anthracomya* and *Naiadites* (*Anthracoptera*); and the present writer, in a paper "On the Occurrence of Marine Fossils in the

* *Quart. Journ. Geol. Soc.*, vol xxii., p. 470.

Coal-measures of North Staffordshire" *Trans. North Staff. Nat. Field Club*, (vol. xxix., p. 129), gives a *résumé* of the marine beds previously recorded, together with a description of a new horizon with a marine fauna at Longton.

In 1896, Dr. Wheelton Hind published Part III. of his Monograph (Palæont. Soc.), dealing with the genera *Carbonicola*, *Anthracomya* and *Naiadites*. The "*Proceedings of the Royal Physical Society of Edinburgh*" for the same year (vol. xiii., p. 233) contains a paper by Mr. R. Kidston, "On the Occurrence of *Sphenopteris communis*." The specimen referred to was derived from shales below the Moss Coal, Adderley Green, Longton.

In 1897, Mr. Kidston contributed to the *North Staffs. Nat. Field Club* (vol. xxxii., p. 127), some "Additional Records and Notes on the Fossil Flora of the Potteries Coalfield," while a further contribution by the same author to the "*Transactions of the Royal Society of Edinburgh*" (vol. xxxv. part 1, p. 318) relates to a species of fossil fern (*Neuropteris plicata*) from shale above the Great Row Coal, Longton.

In 1899, Dr. W. Hind in a paper (*Quart. Jour. Geol. Soc.*, vol. lv., p. 365) "On three new species of Lamellibranchiata from the Carboniferous Rocks of Great Britain" describes a new species of *Anthracomya* (*A. calcifera*), and one of *Carbonicola* (*C. Vinti*) obtained from this district.

From this date onwards considerable attention has been paid to the occurrence of marine beds in the Coal-measures of the district.

In 1900, the present writer recorded a new marine horizon in a paper (*Trans. North Staffs. Nat. Field Club*, vol. xxxiv., pp. 87–92), "On a Newly Discovered Marine Bed in the Coal-measures of North Staffordshire." In the same volume (pp. 93–94) a new species of mollusc (*Scaldia minuta*) is described by Dr. W. Hind. In the following year (1901), Mr. J. T. Stobbs announced the discovery "Of a new Marine Bed in the Coal-measures at Leycett, North Staffordshire" (ibid., vol. xxxv. (1901) p. 110); and in another communication (ibid., vol. xxxvi., pp. 86–89) he described the occurrence of a marine bed below the Moss Coal at Sneyd Colliery, near Burslem. To this, Dr. W. Hind contributed a few notes on a species of *Myalina* (*M. compressa, Hind*) from the marine bed. In 1901, Mr. Stobbs, in a paper on "Recent Work in the Correlation of the Measures of the Pottery Coalfield, with Suggestions for future Development" (*Trans. Inst., Min. Eng.*, vol. xxii., p. 229), gave a *résumé* of the marine beds previously discovered, and the result of his researches in endeavouring to trace them throughout the Coalfield.

The same volume contains a paper by Mr. J. Cadman on "The Occurrence, Mode of Working, and Treatment of the Ironstones found in the North Staffordshire Coalfield," in which

reference is made to the characteristic fossils found in the Black-Band Ironstones of North Staffordshire.

The volume issued by the Palœontographical Society for 1901 contains a Memoir by Dr. Traquair on "The Ganoid Fishes of the British Carboniferous Formations," (Part I., No. 2), in which, among other forms, he describes and figures two species of *Elonichthys* (*E. microlepidotus*, and *E. Aitkeni*, the former from the Knowles Ironstone, Fenton, and the latter from the shale over the Bullhurst Coal.

The species of Latyrinthodonts obtained from the Pottery Coalfield and one specimen from the Keuper Sandstone of Stanton are described in the same year.*

In 1903, some interesting discoveries of Fish remains were recorded from a marine bed below the Gin Mine Coal at Nettle Bank Colliery, Smallthorne. One of these consists of an ichthyodorulite, named and described by Dr. A. S. Woodward, in the Geological Magazine (vol. x., Dec. iv., p. 486), as *Listracanthus Wardi*. Mr. E. T. Newton has also placed on record (*Quart. Journ. Geol. Soc.*, vol. lx., p. 1), the occurrence of *Edestus triserratus* from the same bed. Dr. Wheelton Hind has continued his description of the Lamellibranchiata (*Pal. Soc.* Vol. for 1903), among which he figures *Pterinopecten papyraceus* from this Coalfield.

In connexion with the literature bearing on the Palæontology of the Pottery Coalfield, reference may be made to a "Chart of Fossil Shells found in connection with the seams of coal and ironstone of North Staffordshire," by Dr. Wheelton Hind and Mr. J. T. Stobbs, published by the *North Staffordshire Institute of Mining Engineers*. (1903). The coal and ironstone seams are arranged in stratigraphical order and are accompanied by figures of many of the typical forms of shells which characterize each bed.

This summary of research would be incomplete were we to omit to recall the labours carried on by W. Molyneux. He was one of the early pioneers of fossil collecting in North Staffordshire, and from the year 1859 to 1870, he devoted himself assiduously to collecting the organic remains of the district more especially the fauna of the Coal-measures of the Churnet Valley. To his labours we owe many interesting discoveries.

* Ward, J., *Trans. North Staffs. Nat. Field Club*, vol. xxxiv., pp. 101-107.

CHAPTER XXI.

THE FAUNA AND FLORA.

In the following pages an endeavour will be made to convey some idea of the richness of the fauna and flora of the area under consideration, and the various classes of organisms represented, special attention being given to the fishes.

PLANTS.

Remains of fossil-plants constitute an important part of the fossil organisms of the coalfield. Most of the genera and a considerable number of species common to the Coal-measures, have been collected and submitted to Mr. Kidston for determination.* Upwards of 30 genera and about 90 species of fossil-plants have already been determined. It is probable that the list (see Appendix No. 1 and 2) does not represent the total number of plants of the coalfield, but it is hoped that many of the gaps will shortly be filled as mining operations extend.

ANIMALIA.

Echinodermata.—Spines and plates of a species of sea-urchin (*Archæocidaris*) have occurred in abundance in a marine bed at Smallthorne.

Annelida.—This class is represented by two or more species of the genus *Spirorbis.* One species, *S. carbonarius* (=*S. pusillus,* Mart.), is exceeding abundant at a number of horizons, and has an extended vertical range. It is especially characteristic of certain bands of limestone in the upper subdivision of the Coal-measures, to which this little organism has given the title of "*Spirorbis* Limestone." Another species, *S. helicteres,* is rare.

Insecta.—Remains of insects are among the rarest of fossils in the Carboniferous rocks. Only one specimen has been recorded from North Staffordshire. This was recently discovered by Mr. J. T. Stobbs and consists of the wing of an orthopterous insect, *Lithomantis carbonaria.* It occurred in a hard band of shale crowded with plant remains, overlying the Peacock Marl.

Crustacea.—Specimens of the higher orders of this class of organisms are of rare occurrence. Remains of a species of *Dithyrocaris* (*D. testudinea,* scouler) have been obtained

* "The Fossil Flora of the Staffordshire Coalfield," Part ii. *Trans. Roy. Soc. Edinburgh,* vol. xxxvi. (1891), p. 63.

from a marine bed over the "Seven Feet" Bambury Coal (p. 311). A single imperfect example of the genus *Belinurus* (*B. trilobitoides*) has also occurred, and another showing a portion of the body-segments of a *spined* Myriapod (*Euphoberia ferox*). Other Crustacea are abundant, especially Ostracoda (*Carbonia, Beyrichia*), which crowd many of the shales, the genus *Carbonia* being particularly abundant in the bands of "*Spirorbis*" Limestone in the Upper Series.

Brachiopoda. — Among the more abundant fossils appertaining to this class is the genus *Lingula*. *Lingula mytiloides* has a great vertical distribution—extending from the horizon of the Crabtree Coal (p. 308), to the Bay Coal (p. 325), but only in the various marine beds. Other genera are *Chonetes*, 1 species; *Orthis*, 1 species; *Productus*, 2 species; *Athyris*, 1 species; *Discina*, 1 species.

Lamellibranchiata.—This class forms the most important of the Molluscan fauna of the coalfield. In it are included genera represented by numerous species rich in individual specimens. Of the genera considered to be characteristic of fresh-water deposits, Dr. Hind has enumerated in his Monograph † the following as occurring in the area:—*Anthracomya*, 15 species; *Naiadites* (*Anthracoptera*), 6 species; *Carbonicola* (*Anthracosia*) 14 species.

Besides the foregoing, other genera, characteristic of marine beds. are *Myalina*, of which one species (*M. compressa*), has occurred Another well-known genus, *Pterinopecten* (*Aviculopecten*) is represented by two species, *P. papyraceus* and *P. fibrillosus*; the first-named occurs in immense numbers on several horizons; the latter species is a rare form, and has only been recognised on one horizon—a marine bed below the Gin Mine Coal (p. 320). Other genera are *Schizodus*, *Nucula*, *Ctenodonta*, *Nuculana*, *Syncyclonema*, *Posidoniella*

Gasteropoda.—Of this class, which is confined to marine deposits, the following genera have been determined: *Euphemus Bellerophon*, *Macrochilina*, *Naticopsis*, *Loxonema*, *Turbonellina*, *Raphistoma*.

Cephalopoda.—A marine bed below the Gin Mine Coal has furnished a number of genera of this class. Several specimens of *Pleuronautilus armatus* found by Mr Stobbs and a new form with tubercles. *Orthoceras* of two or more species which generally occur flattened by pressure, are common on the horizon above-named. Among other genera there have been determined *Gastrioceras*, *Pleuronautilus*, *Glyphioceras*, *Ephippioceras*, *Stroboceras*, *and Dimorphoceras*.

† *Palæont. Soc.*, vols. for 1894–95, etc.

PISCES.

Remains of fossil fishes, as already observed, form an important portion of the fauna of the Pottery Coalfield. They were among the first fossils which attracted the attention of collectors, and some of the earliest discoveries were submitted to Agassiz, when he was engaged upon his great work "Récherches sur les Poissons Fossiles."

The strata which have yielded the largest number and the best preserved specimens of fishes are the shales immediately associated with the ironstones, while, as a rule, the remains found in shale overlying beds of coal are fragmentary and scattered. Many beautiful and well-preserved examples, however, have been obtained from concretions of ironstone or "nodules," frequently found imbedded in the shales.

The middle portion of the Productive Coal-measures has yielded a large assemblage of fishes, whilst in the lower part, though present, they are of much rarer occurrence.

The fossil fishes hitherto discovered have been principally obtained from a few localities, viz., Longton, Fenton, Adderley Green, Silverdale and Apedale. The two first-named localities have yielded a rich assemblage of ichthyic treasures, among them many rare and unique specimens. From this it may appear that both the beds and localities containing fish-remains are much restricted. There is no doubt that this is true to some extent, but it is possible that future researches may reveal an equally abundant ichthyic fauna in other parts of the area, if the fossils are carefully collected as mining operations are developed. It has been observed "that remains of fishes are not often found over large areas. Even when found to occur in abundance in one locality and on a horizon which extends over a wide area it does not follow that such remains will be uniformly distributed over that area. On the contrary, the fishes are discovered in certain districts, whilst in others the same bed, on the same horizon, is unproductive."

It may be noted that out of the large number of species met with in the district, only two genera, *Edestus* and *Listracanthus*, have so far been found to be restricted to a truly marine bed.

The fossil fish-remains enumerated in the following pages are referable to the Orders Acanthodii, Ichthyotomi, Selachii, Sirenoidei, Crossopterygii, and Actinopterygii.

ORDER ACANTHODII.

Acanthodidæ.—This family, which was common in the Old Red Sandstone strata, is here represented by the genus *Acanthodes*, of which two species have occurred—*A. Wardi*, and *A major*. The first-named species has a greatly extended range. The second species, so far, has only occurred on one horizon, the Knowles Ironstone.

Detached spines of *Acanthodes* are common, and occur in nearly every stratum where fish-remains have been found.

The shales associated with the Deep Mine Ironstone, Longton and Fenton, have, however, yielded a beautiful series of nearly perfect specimens of *A. Wardi.** The occurrence of so many well-preserved examples of Acanthodian fishes is of palæontological interest, as remains of this family of fishes, other than fragmentary, are elsewhere of rare occurrence in strata of Coal-measure age. Of *A. major,*† only fragmentary remains have been obtained. These represent a much larger fish than *A. Wardi.* The distinguishing feature of the species is the small size of the scales which are less than those of the last-named species.

Messrs. Hancock and Atthey have described ‡ and figured certain remains from the Northumberland Coal-measures pertaining to an Acanthodian fish, consisting of a small styliform bone and attached to it a dentigerous bone bearing five or six triangular teeth. For these they proposed the generic title of *Acanthodopsis,* " for the reception of those species hitherto included in the genus *Acanthodes* which, like *A. Wardi,* may have large triangular teeth similar to those alluded to." One species so distinguished was described under the specific title of *Acanthodopsis Wardi.*‡ Specimens of the latter species have occurred in the Deep Mine and Knowles Ironstone, Longton.

ORDER ICHTHYOTOMI.

Pleuracanthidæ.—This family is represented by detached spines and teeth referable to the genus *Pleuracanthus.* Of this genus the following species have occurred :—

Pleuracanthus lævissimus, *Agass.*
" (Orthacanthus) cylindricus, *Agass.*
" robustus, *Davis*
" alatus, *Davis*
" Wardi, *Davis*

Detached teeth, so familiar to collectors under the generic name of *Diplodus* that it is not necessary to describe their general form, occur in abundance in the New Ironstone (Rag Mine) and Deep Mine Ironstone, Fenton and Longton. The commonest form is *Diplodus gibbosus*§. Other, and rarer species, are *D. equilateralis,*¶ and *D. tenuis.*

Teeth of *Diplodus* are now known to be referable to one or other of the *Pleuracanthi.* At present, however, it is impossible to correlate these teeth with any known species.

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* See figures of the fish, *Trans. Roy. Dublin Society* (1894) Ser. xi., vol. v., pl. xxvii-xxix. Also *Quart. Journ. Geol. Soc.* Vol. xxi., p. 468.

† *Ibid,* pl. xxix., figs. 5, 6.

‡ *Annals and Mag. Nat. Hist.* (4) vol. i. (1868), p. 364, pl. xv., fig. 6.

§ See figure " *Trans. North Staffs. Inst. Mining and Mechanical Engineers,*" Vol. x., pl. ii., fig. 3.

¶ Ibid. fig. 2. Also "*Trans. Roy. Dublin Soc.,*" Vol. iv. (Ser. ii.) pl. 2 xxiii, fig. 27.

ORDER SELACHII.

Petalodontidæ.—This family of sharks, remarkable for the peculiar serrated or crenated cutting surface of the teeth, is here represented by three genera and a like number of species, viz.: *Janassa linguæformis*, *Ctenoptychius apicalis*, and *Callopristodus pectinatus.* The first-named genus is exceedingly rare, only one specimen having been obtained.

The genus *Ctenoptychius*, represented by teeth of one species *C. apicalis*,† is common at several horizons, especially in shale overlying the Rag Mine Ironstone, Fenton; the Brown Mine Ironstone, Silverdale; and the Knowles Ironstone, Fenton and Longton. In addition to detached teeth, fragmentary remains of fishes, to which this form of tooth belonged have been found, and these throw light on the general character of the species. They include portions of the body covered with shagreen granules and teeth of the characteristic type attached to the cartilaginous jaws. The type of the genus *Ctenoptychius* was obtained from the coal-shales of Silverdale and was figured by Agassiz.‡ Detached bodies referred to the genus *Callopristodus*,§ are of frequent occurrence in the New Ironstone (Rag Mine) and Deep Mine Ironstone. One species is known, *C. pectinatus*,¶ of which specimens have been obtained showing that in this species there is considerable variation in form, in probably the one species. So far, nothing is known as to the nature and function of these remains. It has been suggested that they might be dermal tubercles. Agassiz, on the other hand, considered them to be teeth of Selachian fishes.

Cochliodontidæ.—This family has here two representatives, the genera *Helodus*, and *Pleuroplax*, (*Pleurodus*, Agass.).

The genus *Helodus* was instituted by Agassiz for the reception of certain forms of teeth represented in rocks of Carboniferous age. The typical species *Helodus simplex*, was founded upon specimens obtained from the coal-shales of Silverdale of which the horizon is not known. This species is not rare in one or two horizons in other parts of the area, especially in a stratum of black shale associated with a thin band of ironstone above the Ash or Rowhurst Coal, Longton. A unique group of forty-two typical teeth of this species from the bed named has been figured by the writer,** but this does not afford any definite information as to the character of the complete dentition, inasmuch as there is evidence of both teeth and spines which had

† Poiss. Foss., vol. iii., p. 99., pl. xix., fig 1, 1a.

‡ "Recherches sur les Poissons Fossiles," vol. iii., pl. xix., fig. 1.

§ "Notes on the remains of some Reptiles and Fishes, etc., etc." *Trans.* "*Nat Hist. Northumberland and Durham*," vol. iii., part i. (1869), p. 115.

¶ "*Trans. North Staffs. Inst. Mining and Mechanical Engineers*, vol. x., pl. ii., fig. 12.

** *Trans. North Staff. Min. Eng.*, vol. x. pl. 11, Fig. 13.

previously been considered to be characteristic of *Pleuroplax* having occurred in direct association with similar teeth of a *Helodont* type. It seems not unlikely that future discoveries may lead to the abolition of the genus *Pleuroplax*, and its inclusion in the genus *Helodus*. In addition to detached teeth of *Helodus simplex*, several almost perfect specimens of the fish have been obtained from the Knowles Ironstone, Longton and Fenton. These show the general form of the body (with the exception of the head which was not well preserved), covered by fine shagreen granules " or placoid scales "; on the dorsal surface there projected a short, deeply and obliquely implanted spine of about 2½ inches in length, a little more than half of which was inserted in the soft parts. Lying within the area of the head were numerous teeth of the typical *Helodus simplex* type, in one or two instances in natural order. Behind the head a number of rod-shaped cartilaginous radials indicate the remains of a large and powerful pectoral fin. Previous to the discovery of these remains, species of the genus *Helodus* were only known from detached teeth. No similar instance of the preservation of the cartilaginous skeleton of *Helodus* had been discovered.

The genus *Pleuroplax* (=*Pleurodus*, Agass.) is represented by detached teeth referable to two species, *P. Rankini* and *P. Attheyi*, which occasionally occur in the shale associated with the Hard Mine Coal, Knowles Ironstone, and several other beds.

As already indicated, teeth and spines assigned to this genus are closely allied, if not identical with similar organs in *Helodus*. The researches of J. W. Davis, supported by Dr. Traquair † tend to show that the two forms represent but one genus. At present, however, the evidence available does not justify this union of the two genera.

Cestraciontidæ.—Only one representative of this family has occurred—the genus *Sphenacanthus*. The remains of this genus consist of detached spines. One species is known, *S. hybodoïdes*, which is of frequent occurrence in the Knowles, Chalky Mine and Brown Mine Ironstones. Detached teeth have been found associated with the spine, thus presumably belonging to the same genus.‡

Ichthyodorulites.— Among the more frequent examples of ichthyodorulites which occur in this locality are spines of the Selachian genus *Gyracanthus*; and these are not rare on several horizons. One species has been recognised, *G. formosus*. A number of well-preserved specimens of this species have been obtained from a stratum of shale associated with a thin band of ironstone above the Ash or Rowhurst Coal; also from the Knowles, and Chalky Mine Ironstone, Longton. An example of this spine has

† Proc. *Roy. Phys. Soc. Edin.* vol. ix., p. 417.
‡ See figure, *Trans. North Staff. Inst. Min. Eng.*, vol. x., pl. 11, Fig. 16.

been figured by the writer.* Associated with spines there have occurred certain peculiar triangular bones, which have been described by Messrs. Hancock and Atthey † as "carpal" bones, "similar to those in connection with the pectoral fins in the Sharks and Dog-fishes." These, however, are now known to be dermal structures.

No teeth or dermal tubercles have been found associated with the spine. As yet, nothing is absolutely known of the affinities of the fish to which the spine originally belonged.

Recently spines of the genus *Listracanthus* have occurred in a marine bed underlying the Gin Mine Coal, Smallthorne, associated with the peculiar stud-like tubercles named by M'Coy, *Petrodus*, the nature and functions of which are as yet unknown. The same bed has yielded the fragment of a fish referred to *Edestus.***

INCERTÆ SEDIS.

Remains of two peculiar genera of Selachian fishes, viz.: *Euctenius*, (*E. unilateralis*,‡), and *Stemmatodus*,§ have occurred, and diverse opinions have been expressed on the nature of these curious bodies. The first-named has been described by Dr. Anton Fritsch under the name of "Kammplatten," and considered to be the cloacal appendage of "*Ophiderpeton*," a "Stegocephalous" amphibian. Dr. Traquair, on the contrary, refers them to the genus *Euctenius*, believing them to be the teeth of fishes. Of the character and functions of *Stemmatodus* nothing absolutely is known. The founder of the genus suggests that they may have occupied the tongue, or back part of the roof of the mouth, from their supposed resemblance to the dental plates of the Devonian genus *Dipterus*. Both genera are not rare in the Rag Mine Ironstone, Longton.

ORDER SIRENOIDEI.

Ctenodontidæ.—This family of fishes is represented in North Staffordshire by the genera *Ctenodus*, and *Sagenodus*. Of *Ctenodus* two species, *C. cristatus* and *C. Murchisoni* occur.

Fine specimens of palato-pterygoids and attached tooth-plates of *C. cristatus* have been obtained, also bones of the cranium, scales, and other remains. A fine example of this species from the Knowles Ironstone, Fenton, showing the disposition of the membrane-bones of the posterior portion of the cranium in their natural order, and a tooth-plate *in situ*, has been figured by Dr. Anton Fritsch.¶

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* *Trans. North Staffordshire Inst. Mining Engineers*, vol. x., pl. 3, fig. 1.

† *Ann. and Mag. Nat. Hist. Ser.* 4 (1868), vol. i., p. 369.

**Newton, E. T., on the occurrence of Edestus in the Coal Measures of Britain. *Quart. Journ. Geol. Soc.*, vol. lx., pages 1–9.

‡ *Trans. North Staffordshire Inst. Mining Engineers*, vol. x., pl. ii., fig. 14.

§ *Ibid.*, fig. 22.

¶ Fauna der Gaskohle und der Kalkstein der Permformotion Bohmens, p 77, fig. 155.

Ctenodus Murchisoni was named by Agassiz but not described. Fine specimens of dental plates of this species have been obtained from the Bassey Mine Ironstone, Longton and Fenton.

ORDER CROSSOPTERYGII.

Rhizodontidæ.—This family has here two representatives, the genera *Strepsodus* and *Rhizodopsis*, each of which is represented by one species.

The remains of *Strepsodus sauroides** which have hitherto occurred consist principally of detached teeth; but several imperfect specimens of mandibular rami bearing teeth have been obtained, together with a large number of vertebræ, and, more rarely, scales. These remains are common in the Knowles and Deep Mine Ironstone shales, Fenton; the Brown Mine Ironstone, Silverdale; and the Gubbin Ironstone, Shelton. Of the genus *Rhizodopsis*, the only known species is *R. sauroides*; but this is one of the most abundant of the Ganoid fishes of the Coal field. It ranges from the base of the Coal-measure throughout the whole vertical thickness of strata, though frequently fragmentary. A fine series of almost perfect specimens has been found in nodules of ironstone in the Knowles Ironstone, Fenton and Longton, and the Cockshead Ironstone, Adderley Green. Small examples of *Rhizodopsis* are of frequent occurrence in a band of dark shale above the Ash or Rowhurst Ironstone, Longton; probably young forms of *R. sauroides*.

Osteolepidæ.—The well-known Coal-measure genus, *Megalichthys*, is here the only representative of this family. Of this genus there occur five species, viz.: *M. Hibberti*, *M. coccolepis*, *M. pygmæus*, *M. rugosus*, and *M. intermedius*. The first-named species is present in great abundance in several horizons and at certain localities—more especially in the shales associated with the Knowles Ironstone, Fenton, which has yielded a number of fine, though fragmentary remains. The Cockshead Ironstone, Adderley Green, has also yielded several fine specimens—among which were one or two perfect examples of the head of large individuals. In the Lower Coal-measures it is not so well preserved, or so common, as in beds higher in the series. The remaining species—with the exception of *M. intermedius*, which is fairly common—occur but sparingly.

Cœlacanthidæ.—Only one genus of this family has occurred, the genus *Cœlacanthus*, represented by *Cœlacanthus elegans*. So far as our researches have extended, it is the most frequent and characteristic fish in the coal-field. In the shales above the Knowles, Deep Mine, Chalky Mine, and Brown Mine Ironstones,

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* *Quart. Journ. Geol. Soc.*, vol. xxii., p. 602, woodcut 3, 1866.

† Figures and Descriptions of British Organic Remains, *Mem. Geol. Survey*, Dec. 12, 1866.

Longton, Fenton, and Silverdale, it is frequently found entire. On other beds, it generally occurs in a disjointed and scattered condition. Huxley, in his memoir on the genus *Cœlacanthus*, figured several specimens from the Coal-measures of North Staffordshire.

ORDER, ACTINOPTERYGII.

Palæoniscidæ.—This family forms a conspicuous feature in the fish-fauna of the area under consideration; ranging through the whole vertical thickness of the geological sequence of strata.

The genus *Elonichthys*, Giebel (*Palæoniscus*, Agass.) is the most abundant of the group. Of this genus there have occurred five species, viz.: *E. Aitkeni*, *E. Egertoni*, *E. semistriatus*, *E. caudalis*, *E. microlepidotus*. Another member of this family, the genus *Cycloptychius*, Young, has one representative—*C. carbonarius*, which, so far as is known, is confined to the shale associated with the Deep Mine Ironstone, Longton and Fenton.

Other members of the group are the genera *Gonatodus* and *Rhadinichthys*. Of the first-named, one species has occurred—*G. Molyneuxi*, which, like the last-named, has only occurred on the same horizon and at the same locality.

The genus *Rhadinichthys*, is represented by four species, viz.: *R. Wardi*, *R. Planti*, *R. macrodon*, and *R. monensis*. The first two species are characteristic of the shale over a thin band of iron-stone above the Ash or Rowhurst Coal, at Longton and Fenton. *R. macrodon*, is a rare form; so far, it has occurred only in the shale over the Knowles Ironstone, Fenton. *R. monensis* is a species characteristic of the lower portion of the sequence and has only occurred in a fragmentary condition.

In the "Annals and Magazine of Natural History," Dr. Traquair records the occurrence of an imperfectly preserved head of a fish of the genus *Eurylepis*, from the ironstone above the Ash or Rowhurst Coal, Longton, to which he has appended the specific name "*anglica*." This was the first recognised appearance of the genus *Eurylepis* in the Coal-measures of North Staffordshire and the first figured English specimen.

Platysomidæ.—Of this family three genera have occurred—*Cheirodus*, M'Coy (*Amphicentrum*, Young), *Platysomus*, and *Mesolepis*. The first two genera and the last were founded on specimens derived from this coalfield.

The genus *Cheirodus* is fairly abundant, particularly in the shales associated with the Knowles and Deep Mine Ironstone, Longton and Fenton. Only one species is known—*C. granulosus*, The type specimen upon which the genus was founded was obtained from the Brown Mine Ironstone, Silverdale.

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* *Ann. and Mag. Nat. Hist.* (6), vol. xiv., pl. ix., Fig. 9, p. 373.

The genus *Mesolepis*, is represented by two species—*M. Wardi*, and *M. scalaris*. This genus has a somewhat restricted vertical range, extending from the horizon of the Cockshead Coal to the Knowles Ironstone. Fine specimens of both species have been collected from the Knowles Ironstone, Fenton, and from this bed the specimens, which served as the types for Dr. Young's description of both species, were derived.*

Of the genus *Platysomus*, one species is known—*P. parvulus*, a characteristic species of the Knowles Ironstone, Fenton, from which locality several hundred specimens have been collected. It is also abundant in the Brown Mine Ironstone, Silverdale and Apedale. The genus *Platysomus* has a great vertical range, extending throughout the whole thickness of the Coal-measures of the area in question.

Isolated scales of *P. Forsteri*, have occurred, but these are very rare.

AMPHIBIA.

Labyrinthodontida.—The remains of several genera of this class of vertebrata, viz.: *Anthracosaurus, Loxomma, Pteroplax,* and *Keraterpeton,* have occurred but rarely.

Several interesting fragmentary remains of *Anthracosaurus* including the posterior extremity of a large mandibular ramus "with eleven large, conical, pointed teeth, laterally compressed and recurved towards the apex,"† have been obtained from the New Ironstone (Rag Mine) Fenton. In addition, ribs, vertebræ, and other bones have been found.

The genus *Loxomma*, is represented by one species—*L. Allmanni* A fine specimen of a mandibular ramus‡ of this species, together with portions of the skulls of several individuals, have occurred in the Chalky Mine Ironstone, Fenton. Other remains referable to this species have been obtained from a band of shale overlying the Ash or Rowhurst Coal, Longton Detached teeth are fairly abundant in the shale immediately overlying the Gubbin Ironstone, Shelton.

The genus *Keraterpeton* is of rare occurrence, only one specimen having been found referred to *K. Galvani*, and has been figured by the present writer. § It was referred to the genus *Urocordylus*, by Miall in 1874 in his "British Association Report" on the Classification of the Labyrinthodonts; and has also been described, with a woodcut by Dr. C. W. Andrews in the *Geological Magazine*, vol. ii. Dec. 4, 1895, p. 81.

Remains of a species of Labyrinthodont, referred with doubt to the genus *Pteroplax* (*P. cornuta*,), have been found in a stratum of shale which comes above the Wood Mine Coal, Longton.

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* See figures of this species. *Trans. Royal Soc. of Edin.*, vol. xxix., pl. iv., Fig. 1-7.; pl. vi., Figs. 1-9.

† For a figure and description of this jaw, see *Ann. and Mag. Nat. Hist.* (*4*), vol. vii., pl. vi.

§ See *Trans. North Staffs. Inst. Mining Engineers* vol. x., pl. ix., fig. 1.

‡ Ibid. pl. ix., fig. 2.

Before proceeding with this part of our subject "the distribution of the organic remains," it may be well to point out that local terminology has been found to be a source of much confusion in determining the stratigraphical succession of the various seams, both of coal and ironstone, in the different areas. Beds known by local names in one district—although persistent over a wide area—cease to bear that name in another, and a most perplexing synonymy has thus arisen. The multiplicity of names has been, and still is, a source of much diversity of opinion and a serious obstacle to the correlation of the strata.

The manner in which beds sometimes thin out rapidly, or change their mineral character within short distances, renders any attempt at correlating them over a wide area a difficult task.

Further, as has been pointed out (page 296), the fossil contents of beds vary in different localities. In one area Fishes prevail, in another Mollusca; some species may be common in one or more areas and rare in others. The correlation of strata on palæontological evidence has already shown good results and when the various horizons have been more minutely studied. they will no doubt afford still more valuable assistance.

CHAPTER XXII.

DISTRIBUTION OF THE ORGANIC REMAINS.

Before proceeding with the general distribution of the fauna and flora it will be advisable to add a few words on the classification of the strata adopted.

By most of those authors, who have hitherto written on the geology of the district, the great thickness of Coal-measure strata of the Pottery Coalfield has been separated into three subdivisions—Upper, Middle, and Lower. The Middle and Lower subdivisions are here included under the term Grey Chief Coal-bearing Series (the measures between the First Grit and the Bassey Mine Coal). For the base of the Middle sub division an arbitrary line was drawn at the Ash Coal, which lies about 1,200 feet befow the Bassey Mine Coal and about three times this distance above the First Grit. The Red and Grey Series (the measures above the Bassey Mine Coal) corresponds with the Upper Coal measures of previous writers That these sub-divisions are more or less of an arbitrary character and do not imply a break in the continuity of the sequence is now generally accepted by local geologists.

The fauna of the Millstone Grits and the beds below is essentially marine, consisting, with the exception of that at Congleton Edge (*see* p. 24), chiefly of Goniatites. A few genera and species of marine Lamellibranchiata occur, but these as well as the Goniatites are not distinctive and reappear on several horizons in the overlying Coal-measures. On the other hand, not a single species of any Coal-measure mollusc has been found below the First Grit, or highest bed of the Millstone Grit Series.

Of the Flora of the Millstone Grit only a very scanty amount of material has been collected. So far it has been found to yield only Coal-measure forms.

An examination of the distribution of the fauna in the two great subdivisions of the Coal-measures shows that the lower subdivision is by far the most prolific, not only in genera and species but in individuals. Thus of the molluscan genera *Naiadites* and *Carbonicola*, each represented by numerous species, which form so important an element in the Grey Chief Coal-bearing series, not one species, excepting the minute and doubtful form *Carbonicola Vinti*, passes above the Bassey Mine Coal. Nor is the paucity of vertebrate fauna in the upper subdivision less remarkable. Of the great number of fishes only three or four genera, and these only in greatly diminished numbers, pass above the Bassey Mine Coal; while certain species, *Cœlacanthus elegans*, and *Acanthodes Wardi*, are generally distributed throughout the Coal-measure sequence.

A closer examination of the tables of fossils (Appendix II., p. 350), however, shows that with regard to the mollusca the great change did not take place at the Bassey Mine Coal, but at the highest marine bed forming the roof of the Bay or Lady Coal, 200 feet below the Bassey Mine Coal. The fishes, however, tell a different story, for many of the genera or species lived on for some considerable time after this latest marine period; being met with in considerable profusion in the Deep Mine Ironstone, 100 feet below the Bassey Mine Coal. Evidently then, the conditions which proved so detrimental to the molluscan life was still suited to the fish-fauna. It is further remarkable that the two genera *Cœlacanthus* and *Acanthodes*, which pass up into the Upper Series, continued to exist in Permian times, of which the fauna is generally accepted to be characteristic of land-locked waters.

To pass now to a few of the more striking instances of the restriction of certain fossils to definite horizons. It will be seen that one of the most interesting features of the district consists in the alternation of marine with estuarine and possibly fresh-water conditions. So far nine marine beds, varying in thickness from a few inches to several feet, and occupying clearly defined stratigraphical positions, have been met with. The fauna is highly distinctive, but, as previously stated, contains a few genera and species occurring in the Millstone Grit and the beds below. In no instance have those lamellibranchs, considered to belong to estuarine or fresh-water forms, been found in the same layer with those of marine habitats. These marine beds, though they constitute a very inconsiderable portion of the Coal-measures, are found widely distributed over the district and with their distinctive fauna afford most important guides to the stratigraphist.

Among the estuarine or fresh-water deposits the restriction of *Anthracomya Adamsi* and *A. pulchra* to the Burnwood Ironstone and of *A. Williamsoni* to the roof of the Hard Mine Coal is regarded as of zonal significance by Dr. Wheelton Hind, among other but less defined life zones in the measures below the Bassey Mine Coal. It should not, however, be inferred that the disappearance of a species implies other than a local extinction, probably due to a change of conditions.

In the beds above the Bassey Mine Coal, *Anthracomya Phillipsi* ranks of zonal value, for, though it is not rare in the beds below, it occurs in countless numbers between the laminæ of the Black-band Ironstones. Still higher in the sequence, the small shell, *Anthracomya calcifera*, is confined to the Newcastle-under-Lyme Group.

As might be expected, the fossil flora constitutes an important feature of the coal-field. In their general distribution, it is at once seen from the tables that the flora follows a different law from that of the fauna, for the plants are nearly as rich in genera and species

above as below the Bassey Mine Coal. As a rule, Plants are rare, and in a fragmentary and generally indeterminable condition, in the marine beds. Certain species and genera are restricted to the Upper Series: among others *Pecopteris arborescens* which Mr. Kidston considers to be a high zonal form throughout England, occurs here and not in the Lower Series. The flora in the Upper Series is represented by numerous species common on definite horizons and has proved of much stratigraphical value. Mr. Kidston considers that the grouping of the plants in the Lower Series indicates that both the Middle and Lower subdivisions of other areas are represented in the Pottery Coalfield, and also that there are more or less defined transitional zones between the lower and middle and between the latter and upper subdivisions.

In the following pages the various fossiliferous horizons will be taken in general order.

MILLSTONE GRIT SERIES.

The shales intervening between the First and Third beds of Millstone Grit have yielded a small, but characteristic marine fauna. Unfortunately good natural sections are rare, but a few scattered exposures in streams and quarries afford occasional opportunities for studying the contents of these beds. Several interesting sections occur in the banks of the river Trent at Knypersley. One of these, about 100 yards east of the "Gawton Stone," Knypersley, shows a series of black shales above the Third Grit, containing a comparative paucity of species of fossils, but an abundance of individual specimens in a fairly good state of preservation.

Among other fossils collected *Pterinopecten* (*Aviculopecten*) *papyraceus*, *Glyphioceras* (*Goniatites*) *bilingue*, *G. reticulatum*, *Orthoceras sp*, have been determined by Dr. Wheelton Hind. Higher up the stream, where it flows through Crowborough Wood, at a point about 200 yards above a foot-bridge leading from the "Lion's Paw" to Knypersley Farm, there occur in the bed of the stream nodules from which were obtained badly preserved specimens of a species of *Glyphioceras*. The position of these fossiliferous shales is about 100 feet below the Third bed of Grit.

At Stockton Brook a small but typical series of fossil plants have been collected from shales which occur between the First and Third beds of Grit. The following species have been determined by Mr. Kidston, viz:—*Alethopteris lonchitica*, *Calamocladus sp. Lepidodendron sp.* and *Lepidostrobus variabilis.*

MEASURES BETWEEN THE FIRST GRIT AND BASSEY MINE COAL.

Following conformably on the top of the Millstone Grit comes the great thickness of strata containing the chief Coal seams and beds of Clay-band and Black-band ironstones.

Horizon of the Crabtree and Two Feet Coals.—The lowest strata from which we have any record of organic life in this division of the Pottery Coalfield are those immediately overlying the Crabtree Coal, which seam occurs at a distance of about 40 yards above the First Millstone Grit (p. 57); and the shales above the Two Feet or 20-inch Coal (p. 57).

At Wetley Moor, where the two coals have been largely worked in the past—as evidenced by the numerous old pit mounds scattered over the surface, a few years ago (1895)—the two coals were wrought by an adit near the top of Eaves Lane, Wetley. From a dark shale forming the roof of the Crabtree Coal, Dr. W. Hind and the present writer collected the following Molluscan forms:—*Pterinopecten* (*Aviculopecten*) *papyraceus*, *Lingula mytiloides*, and species of *Goniatites*. Above this bed came a stratum of dark shale, which yielded remains of Ganoid fishes—*Megalichthys Hibberti*, *Cœaclanthus elegans*, *Rhizodopsis sauroides*, and scales of one or more species of *Palæoniscidæ* not yet determined. Associated with these were remains of Selachian Fishes, referable to *Pleuracanthus* (*Diplodus*, Agass.) *gibbosus*, and fin-spines of *Acanthodes Wardi*. A prominent feature in the fauna of these basal beds is the occurrence of the well-known genus *Carbonicola*, which here had its earliest representative in this district, so far as we have any record. Ultimately the genus became one of the most prolific in species of the Molluscan fauna of the area, several species included in this genus passing up from the horizon in question to high in the Coal-measure sequence. No instance has been met with of the direct commingling of *Carbonicola* and its congeners with mollusca of a marine *facies*; on the contrary the line of demarcation separating the two *facies* has been found to be always clear and distinct.

An interesting section of measures overlying the Crabtree Coal occurs in the banks of a small stream, about 200 yards north-east of Ash Hall, consisting of black shales with a thin band of ironstone crowded with *Carbonicola acuta* (p. 57).

Species of *Carbonicola* have been detected in beds which occur above a little seam of coal at a short distance above the Crabtree Coal, in a brook-section, south of Cluston Brook, 300 yards east of the road leading from Congleton to Newcastle-under-Lyme. Green mentions* the finding of species of *Goniatites*, *Pterinopecten* (*Aviculopecten*), and *Orthoceras* in the roof shale of the Crabtree Coal at the Lee Mill Forges, Biddulph.

This group of beds in other localities has yielded a number of fossils. In 1887, when sinking a shaft at Upper House, Werrington†, at the back of the Board Schools, a bed of grey

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* *Mem. Geol. Survey*, "The Geology of Country round Stockport, Macclesfield, Congleton, and Leek," p. 27.

† See Section of Measures, etc., "*Trans. North Staff. Inst. Mining and Mechanical Engineers*," vol. x., p. 22.

shale was passed through at a distance of 52 yards from the surface, overlying a bed of coal. The shale yielded the following fossils:—

Pterinopecten (Aviculopecten) papyraceus, *Goldf.*
Lingula mytiloides, *Sow.*
Discina nitida, *Phill.*
Schizodus antiquus, *Hind*

Large calcareous nodules imbedded in shale yielded the following Cephalopods, determined by Dr. Wheelton Hind: *Gastrioceras* (*Goniatites*) *Listeri*, and *G. reticulatus*. Among other fossils were scales of Palæoniscid fishes, the commonest form being those pertaining to *Rhadinichthys monensis*, a Lower Coal-measure species. The palæontological characters of these beds clearly indicate that they belong to the horizon of the Crabtree Coal. Other localities, which have yielded a similar marine fauna on the same horizon, have been recorded by Smyth, viz.: Baddeley Edge*, Biddulph, etc.

The same observer refers to the finding of *Pterinopecten* (*Aviculopecten*) *papyraceus* in abundance at Knypersley, in shales "which lie between the 'Winpenny' and the 'Four Foot†' Coal." So far, the horizon from which these remains were said to be obtained has not been located.

Horizon of the Bullhurst Coal.—From a stratum of black shale forming the roof of the Bullhurst Coal which was wrought some years ago by an adit, at Salter's Lane, Hulme, Mr. Molyneux obtained a good specimen of the rare species of fossil fish, *Elonichthys Aitkeni*. The occurrence of this species at this horizon is noteworthy, as it is a characteristic species of Lower Coal-measure strata of other Coalfields. Recently, this species has been detected in the roof-shale of the Woodhead Coal, Foxfield Colliery, Dillhorne.

From the roof-shale of a seam of coal, called the "Muck Row," formerly worked at Baddeley Edge, Mr. Molyneux collected the following fossils:—

Diplodus gibbosus, *Agass.*
Helodus simplex, *Agass.*
Megalichthys Hibberti, *Agass.*
" pygmæus, *Traq.*
Rhizodopsis sauroides, *Will.*

At the Falls Colliery, and at the adjoining Moody St. Colliery, a bed of coal called the "Ironstone Coal"‡ is wrought by an adit. Here, the coal is overlain by a stratum of black shale about 4 feet in thickness, from which have been collected the following organisms:—

* *Mem. Geol. Survey*, "Iron Ores of Great Britain," Part iv., p. 264.
† Ibid. p. 264.
‡ This Coal lies above the Seven Feet Bambury, p. 311.

Elonichthys sp.
Gyracanthus formosus, *Agass*
Megalichthys Hibberti, *Agass.*
" pygmæus, *Traq.*
Rhizodopsis sauroides, *Will.*
Beyrichia arcuata, Bean
Spirorbis sp.

Next succeeds a thin band of ironstone, a few inches in thickness, crowded with fine specimens of *Carbonicola robusta*, *C. turgida*, *C. aquilina*, and *Spirorbis*. This is succeeded with a band made up of layers of compressed specimens of *Carbonicola*.

New Mine Rock.—At Adderley Green Colliery, a bed of light grey rock known as the "New Mine Rock," which occurs above the coal seam last-named, has yielded well-preserved fossil plant-remains. Among these Mr. Kidston has identified the following species:—

Cordaites borassifolius, *Sternb.*
Dactylotheca plumosa, *Artis*
Lepidodendron aculeatum, *Sternb.*
Sigillaria discorphora, *König*
" tessellata, *Brongn.*
Stigmaria ficoides, *Sternb.*
Stylocalamites Suckowi, *Brongn.*

Horizon of the Cockshead Coal.—Next in succession comes a fossiliferous bed of importance from its persistence over a wide area, which occurs at a short distance above a well-known seam of coal—the Cockshead Coal, also known as the "Newpool" Coal at Biddulph, and the "Eight Feet Nabs," or the "Eight Feet Bambury" Coal on the Western side of the coalfield (p. 44).

In the district around Adderley Green, the Cockshead Coal is overlain by a series of light-grey arenaceous shales, with plant-remains belonging to *Neuropteris* and *Calamites*, intercalated with a thin bed of "hussle," and a band of cannel. Above, comes a bed of blue-black shale and a thin, irregular, band of ironstone, more or less of a nodular character.

At each of the localities, where the Cockshead Coal is wrought, the black shale is crowded with Mollusca. the most characteristic forms being *Carbonicola acuta* and *C. acuta* var *rhomboidalis* which occur in abundance, while other species, such as *C. ovalis*, *C. obtusa*, *C. similis* are less abundant.

While the fauna of the shale consists principally of mollusca, remains of Fishes, on the other hand, are restricted to the iron-stone especially such of it as is of a nodular character. Although the number of species of this class of organisms are limited yet a few specimens of palæontological interest have been obtained. The Ganoid fish-fauna comprises *Megalichthys Hibberti*, *Rhizodopsis sauroides*, *Acanthodes Wardi*, *Cœlacanthus elegans*, *Platysomus parvulus*, and *Mesolepis scalaris*. Among Selachian fishes, which the ironstone has yielded, may be mentioned *Gyracanthus formosus*, *Pleuracanthus* (*Orthacanthus*) *cylindricus*, and teeth of *Helodus* and *Pleuroplax*.

In the southern area, the Cockshead Coal is underlain by a group of strata consisting of thin seams of coal and underclays with remains of fossil plants and black shales with fragmentary fish-remains. At the Mossfield Colliery, at a distance of 8 yards below the above-named coal, there occurs a thin band of Cannel crowded with *Carbonicola robusta*, mingled with *Beyrichia arcuata*. This bed also contains detached *Palæoniscid* and *Cœlacanth* fish-scales.

The subjoined is a list of fossils including species found both in the shale and in the ironstone, a short distance above the Cockshead Coal:—

Spirorbis carbonarius, *Murch.*
Carbonicola acuta, *Sow.*
" acuta var. rhomboidalis, *Hind*
" ovalis, *Martin*
" obtusa, *Hind*
" similis, *Brown*
Naiadites carinata, *Sow.*
Megalichthys Hibberti, *Agass.*
" coccolepis, *Young*
Rhizodopsis sauroides, *Will.*
Cœlacanthus elegans, *Newb.*
Acanthodes Wardi, *Egert.*
Mesolepis scalaris, *Young*
Cheirodus granulosus, *Young*
Platysomus parvulus, *Agass.*
Pleuroplax Rankini, *Agass.*
Gyracanthus formosus, *Agass.*
Sphenacanthus hybodoides, *Egert.*
Helodus simplex, *Agass.*

Horizon of the Seven Feet Bambury Coal,—In upward succession we come upon a stratum which has yielded a highly interesting marine fauna at several localities on the western side of the Coalfield.

Mr. Stobbs, to whom the credit is due for first bringing the fossiliferous character of the bed in question to notice, gives the following section showing the position of the bed at the Leycett Colliery *—

	Ft.	In.
Shale with Marine bands	7	0
Shale -	8	0
RIDER COAL, No. 3	0	9
Shale - -	6	6
RIDER COAL, No. 2 -	1	0
Shale -	1	0
RIDER COAL, No. 1	2	0
Shale - -	10	0
BAMBURY SEVEN FEET COAL	5	6

The marine bed was first discovered by Mr. Wilmot Scrivens. According to Mr. Stobbs, the stratum which contains the fossils occurs at a distance of about thirty yards above the Bambury Seven Feet Coal ("Seven Feet Nabs" or "Froggery Coal"). It

* *Trans. North Staffordshire Nat. Field Club*, vol. xxxv. (1901), p. 110.

consists of 7 feet of shale (as shown in the section) in which are enclosed circular or oval nodules usually flattened and very symmetrically shaped, and found with their longer axes parallel to the plane of bedding. "The black shale forming the roof of the No. 3 Rider Coal contains the thin layer of nodules." Fossils have occurred both in the nodules and in the roof-shale.

It will be observed from the subjoined list of fossils that the fauna of this bed is somewhat restricted both in genera and species, but is sufficiently distinct in character to mark its marine facies:—

In Nodules	Pterinopecten (Aviculopecten) papyraceus, *Goldf.* Glyphioceras paucilobum, *Phill* Carbonia sp. Dithyrocaris testudinea, *Scouler.*
In Roof Shale	Pterinopecten (Aviculopecten) papyraceus, *Goldf.* Posidoniella lævis, *Brown* Rhizodopsis sauroides, *Will.*

The most striking palæontological feature in connexion with the fauna of this bed is the occurrence of the remains of *Dithyrocaris,* hitherto unknown in the Pottery Coalfield.

Recent researches have demonstrated that this marine bed is a well-marked and persistent horizon extending over a wide area, and characterized by a similar fauna. As a proof of this, Mr. Stobbs, who has devoted much time and labour in endeavouring to ascertain its range, states that it occurs *in situ* at the Hayes-Wood Colliery, where it yields, in addition to the fauna already referred to, *Lingula mytiloides,* at a distance of about 15 feet above the Seven Feet Bambury Coal. He further records its occurrence at the "Minnie Pit," Halmerend, and Talk-o'-th'-Hill Colliery.* More recently the same observer has detected the bed *in situ* in the underground workings of No. 18 pit, Birchenwood Colliery, Kidsgrove where it is marked by the characteristic fossils.

At the Sneyd Colliery, Mr. Stobbs has collected from a stratum of shale which occurs 12 feet *below* the Seven Feet Bambury Coal, the following fossil-plants: *Pinnularia columnaris,* and *Neuropteris heterophylla.*

Dr. Wheelton Hind has also recorded the occurrence of *Carbonicola similis* on the horizon of the Bambury Coal at the Moss Pits, south-west of Mow Cop, and again at Talk o'-th'-Hill.

Horizon of the Little Mine Coal.†—At an horizon about 40 yards above the Bambury Coal comes the Little Mine Coal, now worked by a foot rail at Brownfield Colliery, Bentilee, near Bucknall. The coal is overlain by a bed of black shale, about 6 feet in thickness, with a band of ironstone running through it. The shale contains a great abundance of compressed molluscan

* *Trans. North Staff. Inst. Min. Eng.*, vol. xxii., p. 242.

† Not to be confounded with the Little Mine Coal below the Ash Coal.

remains; among them are species referable to *Carbonicola robusta* and *Naiadites modiolaris*, mingled with *Beyrichia arcuata*.

*Horizon of the Hard Mine or Sparrow Butts Coal.**—The next fossiliferous bed in the sequence is the Hard Mine or Sparrow Butts Coal (= Muck Row), which is largely worked at various localities in the area under consideration. It is immediately overlain by a thin, hard, cannel-like shale charged with an abundance of remains of fossil-fishes, consisting principally of scales, teeth, and bones of palæoniscid fishes. The principal palæontological feature of this horizon, however, is the large assemblage of molluscan remains which occur in a thick bed of light grey shaly marl above the coal seam. Fossils are obtained principally from flattened concretions of stone distributed generally through the shale. Unfortunately the shells occur in the condition of casts. A single example of a crustacean (*Belinurus trilobitoides*), has been obtained from this horizon enclosed in a nodule of ironstone.

The following fossils have been obtained from this horizon at several pits in the vicinity of Adderley Green:—

Belinurus trilobitoides, *Buckl.*
Anthracomya Williamsoni, *Brown*
,, Williamsoni, *var* obtusa, *Ludwig*
,, subcentralis, *Salter*
,, senex, *Salter*
,, obovata, *Hind*
Naiadites modiolaris, *Sow.*
,, carinata, *Sow.*
,, triangularis, *Sow.*
,, quadrata, *Sow.*
Carbonicola aquilina, *Sow.*
,, nucularis, *Hind*
,, cuneiformis, *Hind*
Cœlacanthus elegans, *Newb.*
Elonichthys sp.

During the sinking of a shaft at the Sneyd Colliery a bed of grey rock was passed through at a distance of 18 yards below the Hard Mine or Sparrow Butts Coal, from which Mr. Stobbs obtained a number of fossil plant-remains, viz.:

Bothrodendron minutifolium, *Boulay*
Mariopteris muricata, *Schloth.*
Calamocladus equisetiformis, *Schloth.*
,, charæformis, *Sternb.*
Annularia radiata, *Brongn.*
Sphenopteris multifida, *L. and H.*
Neuropteris rarinervis, *Bunb.*
,, heterophylla, *Brongn.*
Alethopteris decurrens, *Artis*
Sphenophyllum cuneifolium, *Sternb.*
,, cuneifolium var. saxifragæfolium, *Brongn.*

* Bowling Alley of Biddulph.

From an horizon 2 yards below the Hard Mine Coal, at Park Hall Colliery (late Weston Coyney), near Longton, Mr. Kidston and the writer obtained the following species of fossil plants:—

Stylocalamites (Calamites) Cisti, *Brongn.*
„ Suckowi, *Brongn.*
Sphenophyllum cuneifolium var saxifragæfolium, *Sternb.*
Sphenopteris obtusiloba, *Brongn.*
Neuropteris heterophylla, *Brongn.*
„ gigantea, *Sternb.*
Mariopteris muricata var. nervosa, *Schloth.*
Lepidophyllum lanceolatum, *L. and H.*

Horizon of the Holly Lanes Bottom Two-Row or Two-Row Coal.—The next fossiliferous horizon above the Hard Mine is the Holly Lane or Two Row Coal. A stratum of black shale by which this seam is overlaid has yielded the following fossils:—

Anthracomya modiolaris, *Sow.*
Naiadites carinata, *Sow.*
Carbonicola robusta, *Brown.*
„ aquilina, *Sow.*

Above the shale, at the Birchenwood Colliery, a bed of grey rock has yielded specimens of *Linopteris Münsteri.* From the same horizon, at Sneyd Colliery, there have been collected:—

Neuropteris tenuifolia, *Sow.*
„ gigantea, *Sternb.*
Mariopteris muricata, *Schloth.*
Sigillaria tessellata, *Brongn.* (at Leycett).

In addition to the foregoing species, there have been obtained from this horizon at Bucknall, the following plant-remains:—

Calamitina (Calamites) varians, *Sternb.*
Stylocalamites Suckowi, *Brongn.*
Neuropteris heterophylla, *Brongn.*
„ rarinervis, *Bunb.*
„ gigantea, *Sternb.*
Alethopteris lonchitica, *Schloth.*
Mariopteris muricata, *Schloth.*
Annularia radiata, *Brongn.*

Horizon of the Bowling Alley Coal.—The Bowling Alley Coal (the Magpie Seam of Biddulph, the Tachin-End, or Top Two Row-Seam of Silverdale, and the Top Two Row Seam of Kidsgrove) is overlain by a stratum of dark shale, which contains an assemblage of molluscan remains which may be termed a "Mussel Band." At the Sneyd Colliery, Mr Stobbs has recorded * the occurrence of two thin calcareous bands with *Spirorbis helicteres* close above the Bowling-Alley Coal. The same bands have been noticed by Mr. E. P. Turner at the Park Hall Colliery; by Mr. E. B. Wain at the Whitfield Colliery, and by Mr. J. A. Cole at the Brown Lees Colliery.

* *Trans. North Staffs. Inst. Mining Engineers*, vol. xxii., p. 240.

The fossils from the Bowling-Alley Coal Seam are:—

Spirorbis helicteres, *Salter*
Carbonicola robusta, *Sow.*
" acuta, *Sow.*
" aquilina, *Sow.*

Above the Bowling-Alley Coal comes a bed of grey rock known as the "Bowling-Alley Rock," rich in remains of fossil-plants. From this bed there have been obtained the following species determined by Mr. Kidston:—

Stylocalamites (Calamites) Suckowi, *Brongn.*
" Cisti, *Brongn.*
Calamocladus equisetiformis, *Schloth.*
Cordaites borassifolius, *Sternb.*
Sphenopteris obtusiloba, *Brongn.*
Neuropteris heterophylla, *Brongn.*
" gigantea, *Sternb.*
Mariopteris muricata, *Schloth.*
" muricata var. nervosa, *Brongn.*
Alethopteris lonchitica, *Schloth.*
" decurrens, *Artis*
Aphlebia crispa, *Gutb.*
Lepidodendron obovatum, *Sternb.*

Horizon of the Ten Feet Coal. — The Ten Feet Coal is overlain by a thick stratum of dark shale, locally known as the "Mussel Bed," mostly composed of a mass of shells forming a solid bed two feet in thickness of compressed shells of *Carbonicola.* This bed is persistent, and has been traced over a wide area throughout the coalfield. From this horizon the following Mollusca have been obtained:—

Carbonicola acuta, *Sow.*
" robusta, *Sow.*
" obtusa, *Hind*
" aquilina, *Sow.*
Naiadites carinata, *Sow.*
" quadrata, *Sow.*

Horizon of the Birches or Old Whitfield Coal.—Fossils are rare at this horizon in the southern area of the coalfield. At the Florence Colliery, Longton, a bed of black shale about 2 feet 3 inches in thickness, which occurs at a distance of about 17 feet below the coal, has yielded specimens of *Carbonicola acuta,* and *C. aquilina.* At the Glebe Colliery, Fenton, the fossiliferous shale occurs at a distance of 25 feet below the Birches Coal.

Horizon of the Yard Coal (Longton).—This coal seam is overlain by a band of hard shale which, in the southern area, has yielded a few remains of fossil fishes, consisting of detached scales and bones of *Megalichthys, Rhizodopsis, Cœlacanthus, Elonichthys,* and teeth of *Diplodus.* Plant remains have been obtained from the roof-shale at the Florence Colliery, among others being fine specimens of *Sigillaria tesselata.*

Horizon of the Moss or Easling Coal (The Single Four Feet Coal).—In upward succession comes the Moss or Easling Coal, an important geological horizon, possessing several interesting

palæontological features. The Moss Coal is immediately overlain by a thin band of cannel of variable thickness, containing numerous fish-remains, more or less fragmentary, consisting of scales of *Cœlacanthus elegans*, and *Elonichthys sp;* teeth of *Megalichthys Hibberti, Diplodus gibbosus, and Helodus simplex.*

In 1894, the Longton Hall Colliery Company, Longton, sank a shaft for the purpose of winning the deeper coals on their estate. On examining the *débris* on the spoil-heap, the writer's attention was directed to large slabs of dark shale crowded with remains of *Lingula mytiloides.* Careful enquiry showed that the position of the shale in the sequence, in which the fossils were contained, was at a distance of about 34 yards above the Moss or Easling Coal. Associated with the *Lingula* were detached scales of a rare species of a Palæoniscid fish (*Elonichthys monensis*).

At a little distance above the Moss Coal there occurs a stratum of dark shale, which yielded the characteristic fauna of this horizon. Of the Mollusca *Carbonicola turgida* is the most common and characteristic fossil. In addition to the latter the following species have been obtained:—

Carbonicola turgida, *Brown*
„ gibbosa, *Hind*
„ acuta, *Sow.*
„ aquilina, *Sow.*
„ subrotunda, *Brown*
„ obtusa, *Hind*
Naiadites carinata, *Sow.*
„ modiolaris, *Sow.*

The shale-band and its included fauna, referred to above, is persistent over a wide area on the southern portion of the coal-field. At Silverdale a similar fauna occurs in the roof-shale of the Four Feet Coal (The Moss or Easling Coal of the Potteries).

It is somewhat remarkable that during the sinking of a shaft at the Sneyd Colliery, recently, the marine bed found above the Moss Coal at Longton was not observed, but Mr. J. T. Stobbs has recorded* marine fossils from a black fissile shale at a distance of about 30 feet below the above-named coal. The position of the marine bed at Sneyd will be best illustrated by the following section in descending order†:—

	Ft.	In.	
MOSS COAL	4	10	
(*a*) Measures -	20	3	
(*b*) Dark shale	0	2	containing *Myalina.*
Measures about	10	0	
(*c*) Black fissile shale	1	1	containing *Lingula.*
CANNEL COAL SEAM	3	10	"called the Moss Cannel at Sneyd, the lower 2 feet is ordinary coal."

* *Trans. North Staffs. Institute Mining Engineers*, vol. xxii., p. 238.
† *Ibid.* p. 248.

It will be observed, from the foregoing section, that between the Moss Coal at the top of the section, and the Cannel Coal at the base, two distinct marine forms occur on distinct horizons. The upper portion of strata (a, b) shades into the next one (c) by insensible gradations. The thin band (b) yielded an abundance of *Myalina compressa*; the lower portion (c) a large assemblage of *Lingula mytiloides*, which latter species passed down into the upper portion of the Cannel Coal which lies at the base of the series in this district. The measures containing the marine fauna above alluded to have been traced under Mr. Stobbs' direction from this locality over a wide area. Mr. W. Plant found the same bed at Berry Hill Colliery at a distance of about 21 feet below the Moss Coal. It has also been detected by Mr. E. P. Turner at the Florence Colliery at a distance of about 15 feet below the same coal seam; and at Silverdale by Mr. W. G. Salt, in proximity to the Four Feet Seam.* (See p. 49).

In 1900, the writer described the occurrence of a marine bed in a marl-pit at Weston Coyney, near Longton. (See sect. p. 66.)

A further visit to the marl-pit led to the discovery of the marine band (c) not previously observed. It consists of a thin band of shale of about two inches in thickness, which yielded *Pterinopecten papyraceus*, *Lingula mytiloides*, *Discina nitida*, together with fish-remains, consisting of scales and bones of *Elonichthys monensis* (a species rarely seen at so high an horizon), *Cœlacanthus elegans*, *Rhizodopsis sauroides*. This is succeeded by a stratum of red clay (b) enclosing calcareous nodules of a bright red colour, from which have been obtained well-preserved specimens of *Pterinopecten papyraceus*, together with a single example of a new species of *Pleuronautilus*. Remains of Acanthodian fishes are also of frequent occurrence. In upward succession come irregular bands of red, calcareous rock (a) with an assemblage of a curious little organism, which has been figured and described† by Dr. Wheelton Hind under the name of *Scaldia minuta*, and an indeterminable species of *Myalina*. A still more recent visit revealed a thin band of purple clay, underlying a calcareous band, near the top of the Marl-pit. It is crowded with small examples of *Anthracomya*. A few feet below the marine bands there occurs a thin stratum of about six inches in thickness, composed of molluscan remains, chiefly those of *Naiadites modiolaris*. Below this comes a thin band of purple clay. The upper surface is completely covered with fish-remains—a veritable bone bed—including numerous species of Fishes.

No exact information is, however, available as to the position of the strata here referred to in the geological sequence of the district. In its general character it is similar to strata which

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* *Trans. North Staffs. Nat. Field Club*, vol. xxxiv. pp. 87-92.

† *Ibid.* pp. 83-94., pl 1. figs. 1-2.

occurs in a road cutting leading from Bentilee to Pool Dole Fenton, which, presumably, lies between the Yard and Moss or Easling coals.

Horizon of the Gin Mine Coal.—We have now reached an interesting series of strata largely of fresh water origin, though containing several marine beds which, while they present many points of lithological resemblance to one another, are distinct in the character of their fauna, so as to clearly distinguish them from the underlying and overlying deposit.

One of these interesting marine beds has recently been observed in the underground workings of the Florence Colliery, Longton. Here a bed of hard, bluish-black shale, which occurs at a distance of about 18 yards *below* the Gin Mine Coal, has yielded a small, but typical marine fauna, including *Nuculana acuta, Chonetes laguessiana, Raphistoma radians, Lingula mytiloides,* spines of *Archæocidaris,* and *Orthoceras.* This list, although scanty, probably does not represent the whole fauna, and a more careful and extended search will doubtless add many species.

At other localities and on the same horizon, there occurs one of the most prolific marine beds, and the most important of the whole series, both on account of the large assemblage of organic remains it has yielded and also of the extent of area over which it can be traced. The bed in question, it may be mentioned, is high up in the Coal-measures, occurring at a distance of about 430 yards below the Bassey Mine Ironstone. The marine character of the fauna was first noticed during the sinking of a shaft as far back as 1865, at the Speedwell Colliery, Longton. The fossils were found in a bed of dark grey shale or "clunch," and, although dwarfed in their growth, were well preserved. An analysis of the list of fossils collected from this bed shows the following results: the Brachiopoda are less abundant than the Lamellibranchiata, being represented by two genera and species only; the Lamellibranchiata are represented by six genera; the Gasteropoda by two genera, and the Cephalopoda by three. The following species of fossils were obtained from this locality:—

Nucula gibbosa, *Flem.*	Chonetes laguessiana, *de Kon.*
Pterinopecten papyraceus, *Goldf.*	Spirifera sp.
Posidoniella sp. nov.	Macrochilina sp.
Schizodus antiquus, *Hind*	Raphistoma radians, *de Kon.*
Syncyclonema carboniferum, *Hind*	Glyphioceras sp.
Solenomya primæva, *Phill.*	Orthoceras sp.
	Pleuronautilus sp.

The apparent neglect hitherto observed as regards the collecting of fossils from the above horizon is due to the rare opportunities which occur, as the Gin Mine Coal is nowhere worked, and it is only during the sinking of a shaft that an opportunity for research presents itself. It is remarkable that although the fossiliferous character of the strata by which the

Gin Mine Coal is underlain was known as far back as 1865, it has not been met with elsewhere in the district until quite recently.

We are indebted to Mr. J. T. Stobbs for the discovery of a marine bed at another and widely separated locality from that of Longton, which has resulted in the accession of a large and valuable series of organic remains to the fauna of the Pottery Coalfield.

Mr. Stobbs' attention was recently directed to the *debris* lying upon the spoil-heap from a pit-sinking at the Nettle Bank Colliery, Smallthorne. The result was the discovery of numerous marine organisms similar to those obtained from the Gin Mine, Longton.

At the Nettle Bank Colliery the strata containing the marine fossils is about 25 feet in thickness. It consists, for the most part, of a series of dark shales with a band of bluish-black, hard, calcareous rock, about 14 inches in thickness, weathering to a buff-colour on exposure. This rock makes a marked feature in the section, and has yielded a large assemblage of organic remains, including the genera *Chonetes, Athyris, Productus, Spirifera, Glyphioceras, Raphistoma,* and spines of *Archæocidaris.*

The fossils obtained at Smallthorne contain many of the same species as those found at Longton, and would therefore appear to come from the same horizon. There is however this difference —the fauna at Smallthorne is richer, both in genera and species, than at Longton.

The rock is immediately overlain by a stratum of finely laminated, calcareous, dark grey-shale, which has yielded a series of Gasteropods, Cephalopods, Lamellibranchs, and Echinoidea. Among the more characteristic fossils are *Chonetes laguessiana, Nucula gibbosa, Athyris ambigua,* and spines of *Archæocidaris,* the latter here met with for the first time in the Pottery Coalfield.

Next in succession there occurs a band of shale which splits into thin slate-like laminæ. This band is characterised by the presence of *Pterinopecten papyraceus, Pseudamusium fibrillosum,* and a new species (*Syncyclonema carboniferum*). Numerous calcareous, nodular concretions occur in the shale enclosing remains of fossil fishes, viz : *Acanthodes, Platysomus, Elonichthys,* etc., but the distinctive palæontological feature of these nodules is the occurrence of the spines of *Listracanthus,* and the curious stud-like tubercles called *Petrodus* by M'Coy, here met with for the first time in the district.* Another interesting feature in connection with the fish-fauna of this horizon is a specimen obtained by Mr. Pringle, the fossil collector of the Geological Survey. The specimen has been determined by Mr. E. T. Newton† to be a portion of *Edestus triserratus,* and this is a fact of special importance, inasmuch as it is the first record of the genus in Great Britain. Near the top of the fossiliferous

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* *Geol. Mag.,* Dec. iv., vol. x., p. 486.

† *Quart. Journ. Geol. Soc.,* vol. lx. p. 1., 1904.

beds are found *Lingula mytiloides*, and more rarely *Discina nitida*. Fragmentary remains of fossil plants occur, but these are sparingly distributed and difficult of identification.

FOSSILS FROM BELOW THE GIN MINE COAL, NETTLE BANK COLLIERY. *

Echinoidea.

Crinoid ossicles.
Archæocidaris sp.

Brachiopoda.

Athyris ambigua, *Sow.*
Chonetes laguessiana, *De Kon.*
Discina nitida, *Phill.*
Lingula mytiloides, *Sow.*
Orthis sp.
Productus semireticulatus, *Mart.*

Lamellibranchiata.

Ctenodonta undulata, *Phill.*
Nucula gibbosa, *Flem.*
Nuculana acuta, *R. Eth, Jun.*
„ Sharmani, *R. Eth, Jun.*
Posidoniella lævis, *Brown.*
„ sulcata. *Hind*
Pseudamusium fibrillosum, *Salter*
Pterinopecten papyraceus, *Goldf.*
„ carbonarius, *Hind*
Schizodus antiquus, *Hind*
Syncyclonema carboniferum, *Hind*

Gasteropoda.

Euphemus Urei, *Flem.*
Loxonema sp.
Macrochilina sp.
Naticopsis consimilis, *De Kon.*
Raphistoma radians, *De Kon.*
Turbonellina cf. formosa, *De Kon.*

Cephalopoda.

Dimorphoceras Gilbertsoni, *Phill.*
Ephippioceras bilobatum, *Sow.*
Glyphioceras diadema, *Goldf.*
„ micronotum, *Phill.*
„ Phillipsi ? *Foord & Crick*
„ reticulatum, *Phill.*
Gastrioceras carbonarium, *Von Buch.*
Orthoceras sulcatum, *Flem.*
Pleuronautilus n. sp.
Stroboceras sulcatum, *J. de C. Sow.*
Nautiloid, n. sp.

Pisces.

Acanthodes Wardi, *Egert.*
Cœlacanthus elegans, *Newb.*
Edestus triserratus, *E. T. Newton.*
Listracanthus Wardi, *A. S. Woodw.*
Megalichthys Hibberti, *Agass.*
„ intermedius, *A. S. W.*
Orodus sp.
Rhizodopsis sauroides, *Will.*
Sphenacanthus hybodoides, *Egert.*
Stemmatodus sp.
Platysomus parvulus, *Agass.*

Plantæ.

Plant remains not determinable.

That the fauna at Nettle Bank has proved so rich is due to a stoppage of sinking operations for several months, so that an opportunity was afforded of a more thorough working out of the fauna than was possible at Longton.

At the Chell Colliery there have been obtained from a bed of shale which occurs at a distance of 36 feet above the "Twist Coal" seam the following plant remains:—*Neuropteris obliqua*, Brongn. *Neuropteris gigantea*, Sternb. *Neuropteris heterophylla*, Brongn. *Sphenopteris latifolia*, Brongn.

Horizon of the Little Mine or Burnwood Ironstone.—After an interval of about 170 feet, we come to an horizon in which remains of Molluscs make up the fauna. This bed occurs at a distance of about 30 yards below the Ash or Rowhurst Coal. In the southern portion of the coalfield this bed is known as

* It is desired to acknowledge the kind help of Mr. G. C. Crick in the determination of the Cephalopoda. The majority of the fossils enumerated in this list are represented also in the collection of the Geological Survey, which in addition includes *Nucula oblonga*, M'Coy and *Ephippioceras costatum*, Foord.

the "Little Mine" Ironstone; while at Golden Hill, Pitt's Hill, and Newchapel it is known under the name of the "Burnwood" Ironstone. At each of these localities it abounds with a well-preserved and characteristic molluscan fauna.

While the fauna of this bed does not afford a great number of species, individuals are fairly abundant, and of such a character as to be of value in defining the stratigraphical horizon of the bed in which they occur.

The characteristic organism in both locolities is the remarkably fine bivalve, *Anthracomya Adamsi*, which is fonnd more particularly in the upper laminated portion of the bed. This species, so far as yet known, is confined to this horizon, a fact of some importance, as it gives to it a distinct palæontological character, and thus affords valuable data for stratigraphical correlation. *A. Adamsi* is generally accompanied by a closely-allied form, *A. Adamsi* var. *expansa* and more rarely by *A. dolabrata*.

At each of the above-named localities, in addition to *A. Adamsi*, there occur in the New Mine Ironstone which overlies the Burnwood, *A. pulchra* and *Naiadites carinata*.

At Chell Colliery, besides the species above-named, there is another form, *A. Wardi*. The latter species has also been found on the same horizon at the Stafford Coal and Iron Company Collieries, Fenton.

Under the name of the "Little Mine" Ironstone, this bed was formerly worked at the Foley Colliery, Fenton, where it yielded a number of well-preserved fossil plants. Among others, Mr. Kidston identified *Lepidophloios* sp. *Halonia tortuosa*, and *Sigillaria discophora*.

The same authority records the occurrence of *Neuropteris heterophylla* at Chell Colliery, at an horizon about 9 feet above the Burnwood Ironstone.

Horizon of the Ash Coal.—In upward succession comes the Ash or Rowhurst Coal. At a short distance above this seam there comes a bed of bluish-black shale intercalated with a thin band of ironstone. Both deposits have yielded an interesting series of fish-remains.

Among the characteristic forms obtained are two well-marked species of *Rhadinichthys* (*R. Wardi*, and *R. Planti*). A single specimen of a portion of the cranial shield of a small Palæoniscid fish has been described * by Dr. Traquair under the name of *Eurylepis anglica*. Here, too, have occurred teeth and spines of several genera of Selachian fishes, including fine specimens of *Gyracanthus formosus* and *Sphenacanthus hybodoides*. Detached teeth of *Helodus simplex* are not rare. A fine group of teeth of this species, figured by the writer,† was obtained from this bed. Besides the fossils named, there have been found a number of small specimens of

* *Annals and Mag. Nat. Hist.*, Ser. 6, vol. xiv., p. 373, pl. ix., fig. 9.

† *Trans. North Staffs. Inst. Mining Engineers*, vol. x., pl. ii., fig. 13.

Rhizodopsis sauroides (probably young examples of the species), also remains of *Megalichthys intermedius*, and *Cœlacanthus elegans*. A further noteworthy feature in the vertebrate fauna is the occurrence of the remains of Labyrinthodonts; so far as we yet know the lowest horizon at which this class of organisms have occurred in this district. These consist of vertebræ, rib-bones, and portions of the skull referable to *Anthracosaurus Russelli*. From the same horizon, at Longton Hall Colliery, the writer collected and has figured* a single specimen of a small Labyrinthodon—*Keraterpeton Galvani*.

This specimen has more recently been figured and described † by Dr. C. W. Andrews. It is the first recorded example from English Coal-measures. The type of the species was from the Coal-measures, Kilkenny, Ireland.

The subjoined is a list of fossils obtained from strata above the Ash or Rowhurst Coal :—

Sigillaria camptotænia, *Wood.*
Cardiocarpus Gutbieri, *Geinitz*
Pleuracanthus lævissimus, *Agass.*
" cylindricus, *Agass.*
" (Diplodus) gibbosus, *Agass.*
" " tenuis, *A. S. Woodw*
Gyracanthus formosus, *Agass.*
Helodus simplex, *Agass.*
Ctenoptychius apicalis, *Agass.*
Acanthodes Wardi, *Egert.*
Megalichthys Hibberti, *Agass.*
" intermedius, *A. S. Woodw.*
Rhizodopsis sauroides, *Will.*
Cœlacanthus elegans, *Newb.*
Strepsodus sauroides, *Binney*
Anthracosaurus Russelli, *Hux.*
Keraterpeton Galvani, *Hux.*

Mollusca occur in the ironstone, but they are not common. From the roof-shale there have been obtained fossil plants, consisting of *Sigillaria camptotœnia* and *Cardiocarpus Gutbieri*—the latter species at the Glebe Colliery, Fenton.

Horizon of the Brown Mine Ironstone.—The Brown Mine Ironstone, Silverdale, has yielded a large series of fish-remains. The late Mr. Molyneux and the writer collected from the shales immediately overlying the ironstone numerous well-preserved specimens of *Platysomus parvulus*, a characteristic fossil of this bed. Here the type specimen of *Cheirodus* (*Amphicentrum*) *granulosus* was found (Plate v., Figs. 1–7, Appendix).

At Kidsgrove, the same horizon has yielded Selachian remains, principally spines and teeth. Good specimens of *Pleuracanthus lœvissimus*, P. (*Orthacanthus*) *cylindricus*, and *Gyracanthus formosus*, also teeth of *Ctenoptychius apicalis*, and *Pleuracanthus* (*Diplodus*) *gibbosus*.

* *Op. cit.*, pl. ix., fig. 2.
† *Geol. Mag.*, Dec. iv., vol. ii., p. 81.

In the admirable section exposed in the cutting of the mineral railway, Fegg Hayes (Sect. No. 58, Appendix 111), the ferruginous bands on this horizon are crowded with *Naiadites modiolaris*, mingled with *Beyrichia arcuata*. Several of the shale-bands are rich in plant-remains. A thin band of grey ironstone near the top of the embankment, at the northern end of the tunnel, has yielded specimens of *Carbonicola Vinti*.

The following is a list of fossils from the Brown Mine Ironstone:—

Beyrichia arcuata, *Bean*
Anthracomya Phillipsi, *Will.*
Acanthodes Wardi, *Egert.*
Megalichthys Hibberti, *Agass.*
Rhizodopsis sauroides, *Will.*
Cœlacanthus elegans, *Newb.*
Cheirodus granulosus, *Young*
Platysomus parvulus, *Agass.*
Strepsodus sauroides, *Binney*
Ctenoptychius apicalis, *Agass.*
Diplodus gibbosus, *Agass.*

Horizon of the Knowles Ironstone.—In ascending sequence comes the Knowles or Winghay Ironstone. No bed in the coalfield can surpass this in palæontological interest, either as regards variety, beauty of preservation, or number of species contained therein. The most striking palæontological feature, however, is the remarkable assemblage of fishes which have been procured from this horizon. Of this class alone it has yielded twenty genera and thirty species.

The Knowles Ironstone has been largely wrought at Fenton and Longton, and it is from these localities that the fossils here referred to have been obtained.

The ironstone usually occurs in bands separated by finely laminated, bluish-black shale. Fossils are found principally in the shale; the ironstone, however, has yielded many unique specimens.

The fish-remains from this horizon are included in the orders Selachii, Dipnoi, and Ganoidei. One or more genera of Amphibia are also represented.

Of the Selachii the remains are chiefly spines and teeth. They comprise spines of *Pleuracanthus*, three species; *Gyracanthus*, one; *Sphenacanthus*, one; and teeth of *Ctenoptychius*, *Pleuroplax*, *Callopristodus*, *Euctenius*, *Stemmatodus*, and *Helodus*.

A noteworthy feature in connexion with the fish-fauna is the occurrence of several almost entire specimens of *Helodus simplex*, a genus which occurs in the Carboniferous Limestone. Previous to the finding of these remains it was known to collectors only by detached teeth.

The Dipnoi are represented by the genera *Ctenodus* and *Sagenodus*. Of the first-named, two species have occurred, (*C. cristatus*, and *C. Murchisoni*). A specimen of *C. cristatus*, showing a large portion of the skull and a palatal tooth, obtained from this horizon, has been figured by Dr. Anton Fritsch in his

Fauna der Gaskohle (vol. ii., p. 77, fig. 55).] Of the Ganoidei, the family of the *Platysomidæ* has here three representatives, *Platysomus, Cheirodus,* and *Mesolepis.* Of the first-named, *Platysomus parvulus,* from its abundance, may be said to be the most characteristic fossil of the bed. Other members of the family, viz., *Cheirodus granulosus, Mesolepis Wardi,* and *M. scalaris* occur, the two latter but rarely. The type specimens ot both species were obtained from this bed.

The genus *Megalichthys* is here represented by four species, *M. Hibberti, M. intermedius, M. rugosus, M. coccolepis.* A large series of remains of these species have been obtained, consisting of jaws, vertebræ, teeth, and portions of the head and trunk. The genus *Cœlacanthus* is represented by one species, *C. elegans,* as is also *Rhizodopsis* (*R. sauroides*), both being very abundant.

Of the Palæoniscidæ the following species, which, however, are not common, have occurred, viz.: *Elonichthys semistriatus, E. caudalis, E. oblongus, E. Egertoni, E. microlepidotus.* The type specimen of each of the four first species were derived from this horizon. A single specimen of a new species of *Rhadinichthys* (*R. macrodon*) has occurred at Fenton on the same horizon.

Of the higher order of the vertebrata, the Knowles Ironstone has yielded several interesting remains referable to *Loxomma Allmanni.* These consist of a mandibular ramus, vertebræ, ribs, scutes, and portions of the skull.

Mollusca are present, but not in abundance. Several species of *Naiadites* have been obtained in the associated ironstone.

In addition there have been obtained remains of fossil-plants of the following species:—

Lepidodendron serpentigerum, *König*
Sigillaria discophora, *König*
Mariopteris, muricata, *Schloth.*
„ var. nervosa, *Brongn.*
Alethopteris decurrens, *Artis*
„ lonchitica, *Schloth.*
Neuropteris rarinervis, *Bunb.*
Calamitina varians, *Sternb.*
Calamocladus equisetiformis, *Schloth.*

The following list comprises the fauna obtained from the Knowles Ironstone Measures:—

Carbonia fabulina, *J. and K.*
„ fabulina var. angulata, *J. and K.*
„ bairdioides, *J. and K.*
„ pungens, *J. and K.*
„ rankiniana, *J and K.*
Anthracomya minima, *Lud.*
„ var. carinata, *Hind*
„ pumila, *Salter*
„ Phillipsi, *Will.*
Naiadites modiolaris, *Sow.*
„ carinata, *Sow.*
„ elongata, *Hind*

Platysomus parvulus, *Agass.*
Cheirodus granulosus, *Young*
Mesolepis Wardi, *Young*
„ scalaris, *Young*
Acanthodes Wardi, *Egert.*
„ major, *Davis*
Pleuracanthus lævissimus, *Agass.*
„ cylindricus, *Agass.*
„ alatus, *Davis*
„ robustus, *Davis*
„ Wardi, *Davis*
Sphenacanthus hybodoides, *Egert.*
Gyracanthus formosus, *Agass.*

Megalichthys Hibberti, *Agass.*	Diplodus gibbosus, *Agass.*
„ rugosus, *Young*	Ctenoptychius apicalis, *Agass.*
„ intermedius, *A. S Woodw.*	Callopristodus pectinatus, *Agass.*
„ coccolepis, *Young*	Helodus simplex, *Agass.*
Rhizodopsis sauroides, *Will.*	Pleuroplax Rankinei, *Agass.*
Strepsodus sauroides, *Binney*	Euctenius unilateralis, *Traq.*
Cœlacanthus elegans, *Newb.*	Stemmatodus *sp.*
Elonichthys Egertoni, *Agass.*	Ctenodus cristatus, *Agass.*
„ semistriatus, *Traq.*	Sagenodus quinquecostatus, *Traq*
„ caudalis, *Traq.*	Cladodus ?
„ oblongus, *Traq.*	Pteroplax cornuta, *Atthey and Hancock.*
„ microlepidotus, *Traq.*	
Rhadinichthys macrodon, *Traq.*	Loxomma Allmanni, *Hux.*

Horizon of the Priorsfield Ironstone.—A bed of ironstone, known locally as "Prior's Field Ironstone," so named from the workings being situated in a field held in ancient times by the Priory of Trentham, was formerly worked at Longton by "open work." The ironstone lies at a distance of about 36 feet above the "Knowles" Ironstone. It is overlain by a thick stratum of black shale with an intercalated band composed of compressed *Carbonicola*. The peculiar little mollusc called *Carbonicola Vinti* has been found in the ironstone. The same species probably occurs at the same horizon, in thin bands of ironstone in the cutting of the mineral railway between Weston Coyney road and the Uttoxeter branch of the North Staffordshire Railway.

Lingula mytiloides is also met with in the upper portion of the shale, and affords interesting, though scanty, evidence of the incursion of marine life at this horizon.

A thick deposit of light-grey rock, known as the "Knowles Rock," which at Longton lies at a distance of about 40 yards above the Knowles Ironstone, has yielded a good series of fossil-plants. Among others, Mr. Kidston has identified the following:—

Neuropteris rarinervis, *Bunb.*
Linopteris Münsteri, *Eichw.*
Sphenophyllum cuneifolium, *Brongn.*
„ latifolia, *Brongn.*

Horizon of the Bay Coal.—The next fossiliferous horizon to be noticed is one of geological interest because of the extent of area over which it can be traced, and its value as a bench-mark for correlating purposes.

It was first discovered by the present writer in 1863 during the sinking of a shaft at the Foley Colliery, Longton. It consists of a stratum of dark grey shale about 11 feet in thickness, with small flattened concretions of ironstone, overlying a seam of coal called the "Bay" Coal. From the shale were obtained the following marine fossils, determined by the late J. W. Salter:—

Lingula mytiloides, *Sow.*
Discina nitida, *Phill.*
Orthoceras sp.
Pterinopecten papyraceus, *Goldf.*
Productus sp.
Spirifer sp.
Palæoniscid scales.

All these fossils were dwarfed, and seemed to have lived under conditions unfavourable to the existence of marine life. Fragmentary remains of fossil-plants were sparingly distributed throughout the shale. The most common species were:—*Sphenophyllum cuneifolium*, *S. latifolium*, and *Mariopteris muricata.*

The marine bed was immediately overlain by a thin stratum of shale, about two feet in thickness, from which specimens of *Carbonicola* were obtained.

In the area around Chell, the Bay Coal is known as the "Lady Coal." We are indebted to Messrs Stobbs and Turner for their careful researches in connexion with this bed, with the object of correlating it with the Bay Coal of Longton. By comparing the stratigraphical position of the bed in the two areas, it was found that the distinctive lithological and palæontological features, so apparent at Longton, were no less marked at Chell. With the combined evidence there can be little hesitation in endorsing the conclusions which they arrived at as to the correlation of this bed in the two areas.

Horizon of the Rag Mine Ironstone.—Higher in the sequence comes a bed of ironstone known as the "New Ironstone" or "Rag Mine" Ironstone, which, at Fenton, occurs at a distance of about 28 feet above the "Knowles Rock."

The ironstone is overlain by a band of exceedingly hard, finely-laminated, black shale, of which the faunal contents are of a most remarkable character. The band is almost literally crammed with the remains of fossil fishes, consisting of fragments of scales, teeth, spines, and bones of both Ganoid and Selachian Fishes. The abundance of teeth of *Pleuracanthus* (*Diplodus*) *gibbosus* is very conspicuous. Other remains include detached teeth of *Ctenoptychius apicalis*, *Callopristodus pectinatus*, and dermal appendages called "*Stemmatodus.*" Unique specimens of the rare spine called "*Pleuracanthus*" (*Orthacanthus*) *cylindricus*, upwards of 18 inches in length, have been obtained from this bed at Fenton.

Remains of Labyrinthodonts have been found, including a unique example of the mandibular ramus of *Anthracosaurus Russelli*, described and figured by the late Mr. T. Atthey.*

To the west of Fenton, a nearly continuous line of marl pits extends from Queen Street brickyard to Fenton Low. The horizon is said to lie between the New Mine or Rag Mine Ironstone and the Chalky Mine Ironstone (p. 71). The strata exposed in these excavations consists for the most part of grey marls, thin sandstones, and seams of coal. Fossils are not abundant, but one thin band of marly shale at Messrs. Beck and Thompson's brickworks has yielded well-preserved specimens of *Sphenopteris polyphylla.*

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* *Annals and Mag. Nat. Hist.*, Ser. 4., vol. vii., p. 73, fig. 1, pl. vi.

Horizon of the Chalky Mine Ironstone.—The Chalky Mine Ironstone, the next in upward sequence, has been largely wrought at several localities in the Longton and Fenton areas. It usually occurs in bands with partings of shale. Generally this bed is not rich in fossils. One locality, however, (Fenton) has furnished a fairly rich harvest of fossils—especially fossil-fishes, consisting of the remains of *Megalichthys Hibberti, Rhizodopsis sauroides, Cœlacanthus elegans, Acanthodes Wardi,* and *Cheirodus granulosus.* Amphibian remains also occur, including a unique specimen of a mandibular ramus filled with teeth, referable to *Loxomma Allmanni,* which has been figured by the writer.*

The roof-shale has yielded several species of fossil-plants, viz.: *Lepidodendron ophiurus,* and *L. aculeatum, Sphenopteris grandifrons.*

The fossils obtained from this horizon are enumerated in the subjoined list :—

Acanthodes Wardi, *Egert.*
Platysomus parvulus, *Agass.*
Cheirodus granulosus, *Young*
Cœlacanthus elegans, *Newb.*
Rhizodopsis sauroides, *Will.*
Megalichthys Hibberti, *Agass.*
Strepsodus sauroides, *Binney*
Ctenoptychius apicalis, *Agass.*
Callopristodus pectinatus, *Agass.*
Helodus simplex, *Agass.*
Pleuracanthus (Orthacanthus) cylindricus, *Agass.*
" (Diplodus) gibbosus, *Agass.*
Gyracanthus formosus, *Agass.*
Sphenacanthus hybodoides, *Egert.*
Loxomma Allmanni, *Hux.*

Horizon of the Rusty Mine Ironstone.—Next in succession comes the Rusty Mine Ironstone, not now worked. Molluscan remains are the principal fossils which have been obtained from this bed. These include several species of *Carbonicola* and *Naiadites,* together with the little Annelid, *Spirorbis pusillus.*

Horizon of the Gold Mine Ironstone.—A bed of ironstone has been worked at Silverdale called the "Gold Mine Ironstone." This bed appears to occupy a position in the geological sequence between the Ash or Rowhurst Coal, and the Knowles or Winghay Ironstone. It is overlain by a bed of black shale, which has yielded the following fossils:—

Acanthodes Wardi, *Egert.*
Ctenoptychius apicalis, *Agass.*
Cœlacanthus elegans, *Newb.*
Pleuracanthus (Diplodus) gibbosus, *Agass.*
Megalichthys Hibberti, *Agass.*
Rhizodopsis sauroides, *Will.*
Strepsodus sauroides, *Binney*

* *Trans. North Staffs. Inst. Mining Engineers,* vol. x., pl. ix., fig. 1.

Horizon of the Deep Mine Ironstone.—Next in palæontological interest to the Knowles Ironstone comes the Deep Mine Ironstone. This bed has been largely worked at Longton and Fenton. So far, it has not been correlated with any known bed in other parts of the district.

The Deep Mine Ironstone occurs in four bands with partings of finely-laminated, bluish-black shale. The shale has yielded a large assemblage of individual specimens of fossil fishes. The fine state of preservation in which most of the remains occur is without parallel in the Coal-measures of North Staffordshire. The most striking palæontological feature in the fauna of this bed is the comparative abundance of the family of the Palæoniscidœ, which attains its highest development at this horizon, and, although met with in higher beds, is not common. *Elonichthys* is numerically abundant, especially *Elonichthys Egertoni*, of which several hundred examples have been obtained. Other members of this family are the genera *Gonatodus*, and *Cycloptychius*, both of which are restricted to this horizon. Of the first-named, one species has occurred—*G. Molyneuxi*, and of the latter, *C. carbonarius*. The type specimens of both genera were derived from this bed. The family of the *Platysomidœ* has here but one representative, *Cheirodus* (*Amphicentrum*) *granulosus*, which has occurred in a fine state of preservation. The genus *Acanthodes* is represented by one species *A. Wardi*. The specimens of *Acanthodes* obtained from this bed greatly exceed in beauty of preservation any before obtained from British Carboniferous strata. Besides the fossils enumerated, there occur fine examples of *Cœlacanthus elegans*. Remains of Selachian fishes are not common on this horizon (with the exception of detached teeth of *Diplodus gibbosus*, and fin-spines of *Pleuracanthus alatus*, etc.). Remains of Ganoid fishes other than teeth are singularly rare. Teeth of *Megalichthys Hibberti* and *Strepsodus sauroides* are common. The following species have been obtained from this bed:—

Megalichthys Hibberti, *Agass.*
Strepsodus sauroides, *Binney*
Rhizodopsis sauroides, *Will.*
Cœlacanthus elegans, *Newb.*
Elonichthys Egertoni, *Agass.*
Rhadinichthys Planti, *Traq.*
Gonatodus Molyneuxi, *Traq.*
Cheirodus granulosus, *Young*
Acanthodes Wardi, *Egert.*
Pleuracanthus lævissimus, *Agass.*
„ alatus, *Davis*
„ gibbosus, *Davis*
„ lateralis, *Davis*
„ tenuis, *Davis*
„ equilateralis, *Ward*
Stemmatodus sp.
Janassa linguæformis, *Atthey*
Ctenoptychius apicalis, *Agass.*
Callopristodus pectinatus, *Agass.*
Euctenius unilateralis, *Traq.*

Horizon of the Wood Mine Ironstone.—Next in succession comes the Wood Mine Ironstone, with a band of hard, cannel-like shale overlying it. At Swingle Hill Colliery, Longton, where this seam was formerly worked, fossil fishes and plant-remains have been obtained. The latter included *Lepidodendra* and *Sigillaria*.

Horizon of the Cannel Mine Coal.—The Cannel Mine Coal next succeeds. The roof-shale has yielded *Spirorbis pusillus* and teeth of *Ctenoptychius apicalis,* and *Pleuracanthus* (*Diplodus*) *gibbosus*.

At the Clanway Colliery, Tunstall, the following plant-remains, identified by Mr. Kidston, have been obtained from a stratum of shale below this coal:—

Neuropteris heterophylla, *Brongn.*
„ gigantea, *Sternb.*
„ rarinervis, *Bunb.*
Calamites varians, *Sternb.*
Stylocalamites Suckowi, *Brongn.*
Calamocladus equisetiformis, *Schloth.*
Cordaites borassifolius, *Sternb.*

Horizon of the Great Row Rock.—In the southern portion of the coalfield, at a distance of about 6 feet above the Great Row Coal, a thick bed of grey rock or "clunch," is locally known as the "Great Row Rock." The bed is especially rich in well-preserved specimens of fossil-plants. There have been obtained a large number of specimens, which Mr. Kidston has identified as follows:—

Alethopteris lonchitica, *Schloth.*
Calamites approximatus, *Brongn.*
Eucalamites ramosus, *Artis*
Linopteris Münsteri, *Eich.*
„ obliqua, *Bunb.*
Calamocladus equisetiformis, *Schloth*
Lepidodendron aculeatum, *Sternb.*
Mariopteris nervosa, *Brongn.*
Neuropteris heterophylla, *Brongn.*
„ gigantea, *Sternb.*
„ rarinervis, *Bunb.*
„ plicata, *Sternb.*
„ Scheuchzeri, *Hoff.*
Pecopteris nervosa, *Brongn.*
Sphenophyllum cuneifolium, *Sternb.*
„ cuneifolium var saxifragæfolium, *Sternb.*
Sphenopteris grandifrons, *Sauv.*
Sigillaria tessellata, *Brongn.*
„ Brardi, *Brongn.*
„ discophora, *König*
„ Sauveuri, *Zeiller*
Stigmaria ficoides, *Sternb.*

Horizon of the Gubbin Mine Ironstone.—This is a horizon of palæontological interest.—The Gubbin Ironstone, is wrought principally at Shelton Colliery, Cobridge, and the immediate district. The ironstone occurs in bands with partings of hard,

close-grained, laminated shale, the laminæ being crowded with compressed specimens of *Anthracomya Phillipsi* and Entomostraca. The shales have yielded an interesting series of Fish and Amphibian remains. The caudal half of a specimen of *Megalichthys Hibberti*, now preserved in the Museum of Practical Geology, was obtained from the Gubbin Ironstone, Shelton. Besides teeth and spines of Selachian fishes, a number of fine examples of the teeth of *Loxomma Allmanni* have been obtained from a thin band of shale overlying the top band of ironstone. Teeth of *Strepsodus sauroides* and *Pleuracanthus* (*Diplodus*) *gibbosus* occur on the same horizon. The Gubbin Ironstone is the highest horizon at which remains of Amphibia have yet been obtained in this district.

Horizon of the Peacock Coal.—In upward succession comes a considerable thickness of strata, for the most part rich in plants which occur with more or less frequency throughout the whole mass. They are, however, more especially abundant on certain horizons whose exact position in the sequence is well defined.

An horizon which has furnished a number of plant-remains is a bed of light grey marl overlying the "Peacock Coal," and known locally as the "Peacock Marl." The marl is quarried at Longton, Fenton, Joiners Square, Hanley, Cobridge, and several other localities and a similar flora included in the following list is met with in all these localities.

Neuropteris rarinervis, *Bunb.*
„ gigantea, *Bunb.*
Linopteris Münsteri, *Eich.*
„ obliqua, *Bunb.*
Pecopteris plumosa, *Artis*
„ Miltoni, *Artis*
Sphenophyllum cuneifolium, *Sternb.*
Dictyopteris obliqua, *Bunb.*
Lepidophyllum triangulare, *Zeiller*
Sigillaria ichthyolepis, *Corda*
„ scutellata, *Brongn.*
„ Brardi, *Brongn.*
Lepidodendron ophiurus, *Brongn.*
Stigmaria ficoides, *Sternb.*

One of the latest additions to the fauna of the coalfield is that of the wing of an orthopterous insect *Lithomantis carbonaria*, obtained by Mr. J. T. Stobbs from a hard shale band, rich in plant-remains, overlying the Peacock Coal. at the Oldfield Brickworks, Fenton.

Measures above the Bassey Mine Coal.

Black Band Group.—The Bassey Mine Ironstone, which has been adopted as the conventional base (p. 51), is made up of numerous laminæ varying in thickness and colour but generally distinctly showing the lines of deposition. Between each lamina there are found an enormous number of compressed specimens of *Anthracomya Phillipsi, Entomostraca,* and *Spirorbis.* It is

further characterized by exceedingly fine examples of *Stigmaria ficoides*. From the roof-shale, at several localities, *Calamites varians*, *Artisia transversa*, and *Pecopteris nervosa* have been obtained At the Jackfield Colliery, High Lane, near Burslem the following fossil plants have been collected:—

Macrostachya infundibuliformis, *Brongn.*
Sphenophyllum cuneifoliun, *Brongn.*
Lepidodendron lycopodioides, *Sternb.*
Sigillaria discophora, *Konig.*
Pecopteris Miltoni, *Artis*
Neuropteris Scheuchzeri, *Hoffm.*
Linopteris (Dictyopteris) obliqua, *Bunb.*

The Bassey Mine Ironstone is immediately overlain by a hard cannel-like shale, which has yielded the remains of several genera of fossil fishes. The fishes comprise the Dipnoid genus *Ctenodus*, of which two species have occurred: *C. cristatus*, and *C. Murchisoni*; also scales and head bones of the same group. Besides the species named, remains of Ganoids, including *Megalichthys Hibberti*, *Cœlacanthus elegans*, and *Rhizodopsis sauroides*, have been obtained at several localities, Longton Fenton, and Great Fenton.

The other bands of ironstone of the Black Band Group, viz.: the Half-yards, Red Shagg, and Red Mine Ironstones, are each characterized by a similar fauna and flora to that of the Bassey Mine. From the roof-shale of the Red Mine Ironstone, at the Forge Pit, Chesterton, the following plant-remains have been collected:—

Annularia galioides, *L & H.*
Neuropteris macrophylla, *Brongn.*
„ heterophylla, *Brongn.*
„ rarinervis, *Bunb.*
Linopteris (Dictyopteris) Münsteri, *Eichw.*
Alethopteris valda, *Bunb.*
Sigillaria ichthyolepis, *Sternb.*
Lepidostrobus anthemis, *König*

The sequence of strata both above and below the Bassey Mine Ironstone is well displayed in several marl-pits. An interesting section may be seen in "Noden's Marl Pit," near Cobridge Station, and again in a marl-pit at the Hamil, near Burslem Station. In the first-named exposure, there is no difficulty in correlating the strata with other sections in the same group. Here, at a distance of about 23 feet above the Bassey Mine Ironstone, there occurs a band of grey limestone rich in *Carbonia* and *Spirorbis*. This limestone is overlain by a band of black shale with abundance of *Carbonia*, followed by a mottled marl with a similar fauna. At a distance of about 23 feet higher there comes another band of dark, impure limestone, crowded with Entomostraca; a black shale resting upon this is rich in

specimens of *Anthracomya Phillipsi.* Next succeeds a thin band of fine-grained sandstone, about two inches in thickness, with an abundance of a curious little organism, allied to, if not identical with, a fossil described by Kirkby* under the name of *Ancylus Vinti,* and more recently named by Dr. Hind† *Carbonicola Vinti.* The same species is found in the Hamil Marl Pit in a similar matrix. At the latter locality, a black shale (resembling a Black Band Ironstone) with an abundance of *Anthracomya Phillipsi,* forms the summit of the section.

In the area around Longton the first band of *Spirorbis* limestone occurs at a distance of about 36 feet above the ironstone. Here, as in other parts of the district, it possesses constant lithological characters, keeping fairly parallel with the underlying Bassey Mine Ironstone. The limestone abounds—especially on the upper surface—with the little Annelid—*Spirorbis carbonarius* (*S. pusillus*) which has given to this band the term "*Spirorbis limestone.*" Ostracods are abundant; the most common forms are *Carbonia pungens, C. fabulina,* and *C. secans.* Scales of Palæoniscid fishes are not infrequent, and more rarely teeth of *Diplodus gibbosus.*

The following species of fossil plants, named by Mr. Kidston, have been obtained by Dr. Hind from a bed of grey shaly marl above the Bassey Mine Ironstone, at "Hewitt's Marl Pit," Fenton Low.

Mariopteris muricata, *Schloth.*
Neuropteris heterophylla, *Brongn.*
  „ gigantea, *Sternb.*
  „ Scheuchzeri, *Hoffm.*
  „ tenuifolia, *Sternb.*
  „ acuminata, *Schloth.*
Pecopteris Miltoni, *Artis*
Linopteris Münsteri, *Eichw.*
  „ obliqua, *Bunb.*
Calamites varians, *Sternb.*
  „ approximatus, *Brongn.*
Stylocalamites Suckowi, *Brongn.*
Calamocladodus equisetiformis, *Schloth.*
Annularia radiata, *Brongn.*
Macrostachya infundibuliformis, *Brongn.*
Sphenophyllum cuneiformis, *Brongn.*
  „ emarginatum, *Brongn.*
Lepidodendron lycopodioides, *Sternb.*
  „ Wortheni, *Lesq.*
Sigillaria discophora, *König*
  „ ovata, *Sauv.*
Stigmaria ficoides, *Sternb.*
Cordaites borassifolius, *Sternb.*
Artisia transversa, *Artis*
Trigonocarpus Parkinsoni, *Brongn.*

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* *Trans. Tyneside Nat. Field Club,* vol. vi. (1864), p. 220.

† *Quart. Journ. Geol. Soc.,* vol. lv., p. 367.

Reference may be made to a large number of fossil trees found some years ago in Messrs. Hampton's Eastwood Marl Pit at Joiners' Square, Hanley.

In 1867 two large stumps of fossil trees were exposed during the working of the clays. Thirteen additional specimens of fossil were found by the writer in 1880.*

Subsequently Mr. Kidston,† from data supplied by Mr. W Hampton, gave further details, and a table with measurements, of forty-four fossil trees. A reference to the table shows that the trees ranged from 1 foot 7 inches to 18 feet in height, and 1 foot to 3 feet 10 inches in diameter at the top. It is noteworthy that on none of the trees were the roots preserved, " these having apparently decayed before mineralisation took place."

The sequence of the beds is interrupted by a fault which crosses the marl pit, consequently the stratigraphical position of the beds in the sequence of the district cannot be precisely fixed. On the platform upon which the trees stood, a large number of specimens of casts of the pith-cavity of *Calamites*, and stems and fronds of ferns, were scattered around the base of the trees.

The Eastwood Marl Pit is further interesting, not only on account of the fossil trees, but also on account of the abundance of *macrospores* which the shales and underclays have yielded. Mr. Kidston has described and figured § three new forms of *macrospores* from shale which occurs above and below a thin seam of coal. Associated with the *macrospores* he recognised crustacean remains as well as fragments of carbonised stems and other plant *débris*.

An interesting exposure of fossiliferous strata, belonging to the Blackband Group, occurs in an old rail-cutting north of Silverdale Ironworks, consisting of sandstones, shales, and thin bands of ironstone. One thin band of ironstone has yielded several species of Ostracoda—principally *Carbonia fabulina* and *C. rankiniana*, associated with a large species of *Spirorbis*. Other beds are rich in specimens of *Anthracomya. Phillipsi*, plants, and remains of Palæoniscid fishes.

We may here refer to one or two bands of limestone whose position in the sequence is not clear, though they would seem to come somewhere near the boundary line between the Black Band and the Etruria Marl Groups. One of these occurs in a marl pit at the Longton Hall Colliery. It is about four inches in thickness and of a light grey colour. It contains an abundance of Ostracods, the commonest species being *Carbonia pungens* and *C. secans*. *Spirorbis pusillus* is also of frequent occurrence as well as scales of *Cœlacanthus elegans* (p. 115).

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* *Trans. North Staff. Nat. Field Club* (1869), p. 84.

† *Trans. Roy. Soc. Edinburgh*, vol. xxxv., part 11, p. 63.

§ *Ibid.*, pl. 9, fig. B 5-11.

Blocks of limestone have occurred strewn over the floor of Messrs. Challinor's Marl Pit, Fenton (see p.120). We have failed to find the bed *in situ*, from which the blocks have become detached. From these blocks specimens of *Carbonia wardiana*, *C. fabulina* and *C. rankiniana* have been obtained. Scales of Palæoniscid fishes are of common occurrence.

A few observations respecting the so-called beds of *Spirorbis* limestone may not be out of place.

These beds rarely exceed one foot in thickness. They are remarkably persistent in horizontal extension and maintain their lithological and palæontological characters for great distances. The term "*Spirorbis* limestone" has, however, been applied indiscriminately to beds which, in reality, contain few, if any, of the little Annelid. In the stratigraphical account of the coalfield (p. 115), it has pointed out that Ostracods are the prevailing and most characteristic organism of many of these beds. Our own researches extending over many years confirm that statement. In view of these conclusions, it is obviously inappropriate any longer to designate such beds by the term "*Spirorbis* limestone." We propose to distinguish beds in which Ostracods abound to the exclusion of *Spirorbis*, by the title of "Entomostracan limestone."

Etruria Marl Group. — This sub-division includes several fossiliferous beds for the most part characterized by the presence of Entomostraca, which are abundant in one or two beds, especially in a thin bed of limestone near the base of the series which occurs in the Grange Marl Pit, Longport.

In the Heath Marl Pit at Chesterton, the strata exposed includes a thin band of shaly ironstone crowded with compressed specimens of *Anthracomya Phillipsi*. In the same locality, in the "Metallic Brick Pits," there occurs a nodular band of red marly limestone, containing specimens of a large *Spirorbis* (see p. 130).

Newcastle-under-Lyme Group.—This sub-division consists of sandstones, marls, and shales, with four thin seams of coal and two bands of limestone near the base. The most interesting beds in this group are two thin bands of limestone and associated shales invariably met with near the base. A good exposure of these beds occurs in a marl-pit east of Cocknage Hill, Lightwood, where they have yielded *Spirorbis pusillus* and *Entomostraca*, along with *Anthracomya calcifera* and scales of *Cœlacanthus elegans*.

What may certainly be a continuation of the same beds crops out in the roadside cutting above Etruria Railway Station. Excellent exposures may be studied in a series of marl-pits on the hill side to the north; but the best-known exposures are at the Highfield Tileries and the Midland Tileries, Longport.

At the Highfield Tileries two bands of limestone are shown, 11 inches and 5 inches in thickness respectively, with a parting of

shale between them. The limestone and shale parting are exceedingly rich in *Spirorbis* and *Carbonia*. Besides the latter, scales of fossil-fishes are not rare, particularly those of *Cœlacanthus elegans* and *Elonichthys, sp.* Along with the latter, spines of *Acanthodes*, and *Anthracomya calcifera*, occur in abundance. It is clear, judging from the abundance of the organisms found in the shales associated with the limestone that the muddy sediment forming the shales was no bar to their existence.

An interesting section, showing the nature of the strata in the lower part of the group, is exposed at the Midland Tileries. Here, at a distance of about 2 feet above the top band of limestone, there occurs a black shale full of *Carbonia* and a band of red shale with similar organisms.

A good section of the same strata may be seen in the cutting near the mouth of the tunnel at Newcastle-under-Lyme. Here the two bands of limestone are well exposed, and contain the characteristic fauna, including a new species of *Carbonia* (*C. wardiana*) associated with *C. rankiniana*, and *Anthracomya calcifera*.

The species last named appears, so far, to have a limited range. It is common on the horizon in question, and to one or two beds higher in the sequence, but has not been detected lower down. Recently, a deep drain cutting in connexion with the Longton sewage outfall, near the Blurton Tileries, exposed the two limestones. *A. calcifera* was obtained from the overlying shale.

Another exposure of beds on the same geological horizon was made during an excavation for a deep drain by the main road opposite Lord Street, Basford. A cream-coloured finely, laminated, shaly clay yielded an interesting assemblage of fossil plant-remains including, among others, the following species:—

Pecopteris Miltoni, *Artis.*
Lepidophyllum, lanceolatum, *L. & H.*
Calamocladus equisetiformis, *Schloth.*

From red shales associated with a bed of nodular limestone which occurs in the road-cutting from Trentham to Whitmore, Professor Rupert Jones recognised *Estheria tenella*, *Carbonia salteriana*. Spines of *Acanthodes* and scales of Palæoniscid fishes have also been found.

From a dark grey limestone in a road-cutting at Beazley Bank, Chesterton, the following fossils have been collected: *Spirorbis pusillus*, *Carbonia wardiana*, *Anthracomya calcifera*, and scales of *Cœlacanthus* and *Elonichthys* sp.

A highly fossiliferous bed of black shale which crops out near Red Hill Farm, Keele, and is crowded with *Carbonia* probably belong to the same horizon. A similar band of shales, which occurs in an old adit, in Hayes Wood, contains a similar fauna.

Bands of laminated clay occupy well-defined stratigraphical horizons, in this subdivision, and have yielded a rich fossil flora. At Bradwell Wood, near Longport Railway Station, a disused quarry opened in these clays—has yielded a large number of plant remains, including the following :—

Pecopteris arborescens, *Schloth.*
" " var cyathea, *Brongn.*
Alethopteris lonchitica, *Schloth.*
" aquilina, *Schloth.*
Neuropteris Scheuchzeri, *Sternb.*
Lepidostrobus variabilis, *L. and H.*
Stigmaria ficoides, *Sternb.*
Rhabdocarpus sulcatus, *Presl.*
Lepidodendron lycopodioides, *Brongn.*

Similar clays are exposed in the splendid section of strata at the Midland Tileries near Longport Station.

Beds on the same horizon have been traced for a considerable distance. During the cutting of the mineral railway at the Florence Colliery, Longton, a large collection of fossil plant-remains were obtained by Mr. F. Barke, and the writer, viz :—

Pecopteris arborescens *Schloth.*
" var cyathea, *Brongn.*
Alethopteris aquilina, *Schloth.*
Neuropteris ovata, *Hoffm.*
Odontopteris sp.
Calamocladus equisetiformis, *Schloth.*
Sigillaria Brardi, *Brongn.*
Stigmaria ficoides, *Sternb.*

During the making of the tunnel of the Newcastle-under-Lyme branch of the North Staffordshire Railway, a large series of well-preserved fossil plants were obtained, principally by the late Dr. R. Garner. The following species have been determined by Mr. Kidston :—

Sphenopteris grandifrons, *Sauv.*
Pecopteris Miltoni, *Artis*
Neuropteris gigantea, *Sternb.*
Calamitina approximata, *Brongn.*
" rarinervis, *Bunb.*
Lepidodendron ophiurus, *Brongn.*
Lepidostrobus variabilis, *Brongn.*
Stylocalamites Suckowi, *Brongn.*
Calamocladus equisetiformis, *Schloth.*
Lepidophyllum lanceolatum, *L. and H.*
Artisia transversa, *Artis*

Keele Group.—In this the highest subdivision of the Coal-measures of the district, only a few fossiliferous beds have been met with. In a bed of black limestone high in the sequence near Moddershall Lower Mill, and in another bed at Winnington, *Spirorbis* and *Carbonia* are sparingly distributed.

A band of cream-white and apparently unfossiliferous limestone is cut through near Keele Park Station, at a distance of

about 311 feet below a band of dark limestone, 1 foot in thickness, containing *Spirorbis* and *Carbonia*.

The Keele sandstone contains occasional remains of fossil plants. The late Dr. R. Garner obtained the following specimens from Hartshill, which have been determined by Mr. Kidston:—

Sigillaria tessellata, *Brongn.*
Calamites undulata, *Sternb.*
„ Schutzeii, *Sternb.*
„ Cisti, *Brongn.*
„ Suckowi, *Brongn.*

A few fossil plants have recently been obtained from the Keele Group in the boring at Trentham. These are, unfortunately, for the most part difficult to determine. Among them, however, Mr. Kidston has identified *Cordaites* sp. *Pecopteris Miltoni*, and *P. arborescens, var. cyathea*. The two former occur 434 feet above the base of the group.

We have now reached the highest fossiliferous horizon in the Pottery Coalfield at which fossils have been found.

In conclusion, I desire to express my obligations for assistance and courtesies to Mr. R. Kidston, to whose generosity I am greatly indebted for naming the fossil plants enumerated in this account, as well as furnishing a list of fossil plants, from which that in the Appendix has been mainly drawn up. To Dr. Wheelton Hind my thanks are equally due for his kindness in naming the mollusca, not only on this but on every occasion when applied to. Lastly, to Mr. J. J. Stobbs, whose enthusiasm in collecting fossils and readiness in imparting information is beyond praise, and to whom I owe much valuable information, I wish particularly to express my thanks.

The specimens on which the foregoing lists and those in Appendix have been compiled are distributed as follows:

The Fish and Labyrinthodont remains are deposited in the British Museum, Natural History, including the whole of the type specimens which have been found in the coal-field, with the exception of those of *Cheirodus granulosus* and *Edestus triserratus* contained in the collection of the Geological Survey at Jermyn Street. A small series of fishes are in the Museum of Science and Art, Edinburgh. The Mollusca are in the private collections of Dr. Wheelton Hind, Mr. J. T. Stobbs and the writer, and the fossil plants are in the collections of Dr. Wheelton Hind, Mr. R. Kidston, Mr. F. Barke, Mr. J. T. Stobbs and the writer.

APPENDIX No. I.

List of Fossils from the Pottery Coalfield.

By John Ward, F.G.S.

The Measures above the Bassey Mine Coal.

Species.	Horizon.	Locality.
PLANTÆ.		
FILICACEÆ.		
Alethopteris aquilina, *Schloth.*	Newcastle-under-Lyme Group	Rail-cutting, Florence Colliery
		Quarry, Bradwell Wood.
—— lonchitica, *Schloth.*	" " "	" " "
— valda, *Bunb.*	Red Mine Ironstone	Forge Pit, Chesterton.
Linopteris (Dictyopteris) Münsteri, *Eichw.*	27 yds. above Red Mine Ironstone	" " "
	Black Band Group	Newstead boring.
—— obliqua, *Bunb.*	Roof of Red Mine Ironstone	Parkhouse Colliery.
	Bassey Mine Ironstone	Jackfield Colliery.
Mariopteris muricata, *Schloth.*	Black Band Group	Hewitt's Marl Pit, Fenton Low.
Neuropteris ? acuminata, *Schloth.*	" "	Newstead boring.
—— emarginata, *Brongn.*	Newcastle-under-Lyme Group	" "
—— gigantea, *Sternb.*	" " "	Rail-cutting, Newcastle.
	Black Band Group	Hewitt's Marl Pit, Fenton Low.
—— heterophylla, *Brongn.*	Red Mine Ironstone roof	Forge Pit, Chesterton.
	Black Band Group	Hewitt's Marl Pit; Newstead boring.
—— ? macrophylla, *Brongn.*	Red Mine Ironstone roof	Forge Pit, Chesterton.
—— ovata, *Hoffm.*	Newcastle-under-Lyme Group	Rail-cutting, Florence Colliery.
—— rarinervis, *Bunb.*	" " "	Rail-cutting, Newcastle
		Newstead boring.
	Roof of Red Mine Ironstone	Forge Pit, Chesterton.
—— Scheuchzeri, *Hoffm.*	Keele Group	Newstead boring.
	Newcastle-under-Lyme Group	Quarry, Bradwell Wood.
	Bassey Mine Ironstone	Jackfield Colliery.
—— ? tenuifolia, *Schloth.*	Black Band Group	Newstead boring.
Odontopteris. sp.	Newcastle-under-Lyme Group	Rail-cutting, Florence Colliery.
Pecopteris arborescens, *Schloth.*	" " "	Rail-cutting, Florence Colliery.
—— —— var. cyathea, *Brongn.*	Keele Group	Newstead boring.*
	Newcastle-under-Lyme Group	Quarry, Bradwell Wood; Rail-cutting, Florence Colliery.
—— Miltoni, *Artis*	Keele Group	Newstead boring.†
	Newcastle-under-Lyme Group	Rail-cutting, Newcastle; Newstead boring.
	Bassey Mine Ironstone	Jackfield Colliery, Burslem.
Sphenopteris grandifrons, *Sauv.*	Newcastle-under-Lyme Group	Rail-cutting, Newcastle
—— latifolia, *Brongn.*	Red Mine Roof	Forge Pit, Chesterton.
—— sp.	Black Band Group	Hewitt's Marl Pit.
EQUISETACEÆ.		
Annularia radiata, *Brongn.*	Black Band Group	Newstead boring.
—— galioides, *L. & H.*	Red Mine Ironstone	Forge Pit, Chesterton.
Calamatina approximata, *Brongn.*	Newcastle-under-Lyme Group	Rail-cutting, Newcastle.
—— Schutzei, *Sternb.*	Keele Group	Quarry, Hartshill.
—— undulata, *Sternb.*	" "	" "
—— varians, *Sternb.*	Bassey Mine Ironstone	Gt. Fenton Colliery.
—— ?	Keele Group	Newstead boring.

* At 117 and 438 feet from surface. † At 117 feet from surface.

SPECIES.	HORIZON.	LOCALITY.
PLANTÆ.—*continued.*		
Calamocladus equisetiformis, *Brongn.*	Newcastle-under-Lyme Group	Rail-cutting, Newcastle Station and Florence Colliery, Ford Street, Basford
	Black Band Group	Hewitt's Marl Pit.
Macrostachyia infundibuliformis, *Brongn.*	" " "	" " "
	Bassey Mine Ironstone	Jackfield Colliery.
Stylocalamites ? Cisti, *Brongn.*	Keele Group	Quarry, Hartshill.
—— **Suckowi**, *Brongn.*	" "	Quarry, Hartshill; Newstead bore.
	Newcastle-under-Lyme Group	Rail-cutting, Newcastle.
	Black Band Group	Hewitt's and Hampton's Marl Pit.
SPHENOPHYLLACEÆ.		
Sphenophyllum cuneifolium, *Brongn.*	Bassey Mine Ironstone	Jackfield Colliery.
—— **emarginatum**, *Brongn.*	Newcastle-under-Lyme Group	Newstead boring.
	Black Band Group	Hewitt's Marl Pit
LYCOPODIACEÆ.		
Lepidodendron lycopodioides, *Sternb.*	Newcastle-under-Lyme Group	Newstead & Keele bores
	Black Band Group	Hewitt's Marl Pit.
	Bassey Mine Ironstone	Jackfield Colliery.
—— **ophiurus**, *Brong* .	Newcastle-under-Lyme Group	Rail-cutting, Newcastle.
—— **Wortheni**, *Lesq.*	Black Band Group	Hewitt's Marl Pit.
Lepidophyllum lanceolatum, *L. & H.*	Newcastle-under-Lyme Group	Rail-cutting, Newcastle.
Lepidostrobus anthemis, *König*	Red Mine Ironstone	Forge Pit, Chesterton.
—— **variabilis**, *L. & H.*	Newcastle-under-Lyme Group	Quarry Bradwell Wood. Rail-cutting, Newcastle and Florence Colliery.
Sigillaria Brardi, *Brongn.*	Red Mine Roof	
—— **discophora**, *König*	Bassey Mine Ironstone	Jackfield Colliery.
—— **ichthyolepis**, *Sternb.*	Red Mine Ironstone*	Forge Pit, Chesterton
—— **ovata**, *Sauv.*	Black Band Group	Hewitt's Marl Pit.
—— **tesselata**, *Brongn.*	Keele Group	Quarry, Hartshill.
Stigmaria ficoides, *Sternb.*	Newcastle-under-Lyme Group	Quarry, Bradwell Wood. Rail-cutting, Florence Colliery.
	Bassey Mine Ironstone	Florence Colliery.
CORDAITEÆ.		
Artisia transversa, *Artis*	Newcastle-under-Lyme Group	Rail-cutting, Newcastle.
	Bassey Mine Ironstone	Gt. Fenton Colliery.
Cordaites borassifolius, *Sternb.*	Black Band Group	Newstead boring.
—— **sp.**	Keele Group	" "
Rhabdocarpus sulcatus, *Presl.*	Newcastle-under-Lyme Group	Quarry, Bradwell Wood.
Trigonocarpus Parkinsoni, *Brongn.*	Black Band Group	Hewitt's Marl Pit.
ANIMALIA.		
ANNELIDA.		
Spirorbis pusillus, *Mart.*	Keele Group	Rail-cutting, Keele Park; roadside, Moddershall, L. Mill.
	Newcastle-under-Lyme Group	General in basal limestone.
	Black Band Group	General.
—— **sp.**	Etruria Marl Group	Metallic Brick Pit, Chesterton.
ARTHROPODA.		
Beyrichia arcuata, *Bean*	Black Band Group	Sneyd Marl Pit, Burslem.
Carbonia pungens, *J. & K.*	Keele Group, base of	Newstead boring.
	Newcastle-under-Lyme Group	" "
	Black Band Group	Marl Pit, Longton Hall Coll.
—— **salteriana**, *J. & K.*	Newcastle-under-Lyme Group	Roadside, Butterton New Farm. Clay Pit, Lightwood, near Longton.
—— **scalpellus**, *J. & K.*	Keele Group, base of	Newstead boring.
—— **secans**, *J. & K.*	Black Band Group	Marl Pit, Longton Hall Coll.

* 27 yards above Ironstone.

SPECIES.	HORIZON.	LOCALITY.
ARTHROPODA—*continued.*		
Carbonia rankiniana, *J. & K.*	Keele Group, base of	Newstead boring.
	Newcastle-under-Lyme Group	Rail-cutting, Newcastle.
—— wardiana, *J. & K.*	Keele Group, base of	Newstead boring.
	Newcastle-under-Lyme Group	Rail-cutting, Newcastle.
—— sp.	Keele Group	Rail-cutting, Keele Park Station
	Newcastle-under-Lyme Group	General.
	Etruria Marl Group	Grange Marl Pit.
	? Bassey Mine Ironstone	Newstead boring.
Estheria tenella, *Jones*	Newcastle-under-Lyme Group*	Road-cutting near Butterton New Farm.
LAMELLIBRANCHIATA.		
Carbonicola Vinti, *Hind*	Black Band Group†	Marl Pit, Hamil; Newstead bore; Quarry near Ravenscliff House.
Anthracomya calcifera, *Hind*	Newcastle-under-Lyme Group	General near the base.
—— Phillipsi, *Will.*	" " "	Newstead boring.
	Etruria Marl Group‡	Hem Heath Brick Pits.
	Black Band Group	General in Ironstones.
PISCES.		
Acanthodes Wardi, *Egert.*	Newcastle-under-Lyme Group	Not rare in basal limestone.
Cœlacanthus elegans, *Newb.*	" " "	Not rare in basal limestone.
	Etruria Marls, base of	Challinor's Marl Pit, Fenton.
	Bassey Mine Ironstone	Longton, Fenton.
Ctenodus cristatus, *Agass.*	" " "	" "
—— Murchisoni, *Ward*	" " "	Clanway Colliery.
Diplodus gibbosus, *Agass.*	" " " "	Longton, Fenton, Hanley.
Elonichthys, sp.	" " " "	" " "
Megalichthys Hibberti, *Agass.*	" " " "	" " "
Rhizodopsis sauroides, *Will.*	" " " "	" " "

THE MEASURES BETWEEN THE FIRST GRIT AND BASSEY MINE COAL.

SPECIES.	HORIZON.	LOCALITY.
PLANTÆ		
FILICACEÆ.		
Alethopteris aquilina, *Schloth.*	Doubtful	Tunstall.
	Roof of Hard Mine Coal	Adderley Green Colliery.
—— decurrens, *Artis*	Knowles Ironstone	Gt. Fenton Colliery.
	Bowling Alley Rock	Adderley Green Colliery.
—— lonchitica, *Schloth.*	Gt. Row Coal roof	Longton.
	Knowles Ironstone	Longton, Fenton.
	Ten Feet Coal	Chesterton.
	Bowling Alley Rock	Adderley Green Colliery.
	Holly Lane Coal	Bucknall.
	85 yds. below Hard Mine Coal	Sneyd Colliery.
Aphlebia ? crispa, *Gutb.*	Bowling Alley Rock	Adderley Green.
Dactylotheca plumosa, *Artis*	Roof of Peacock Coal	Glebe Colliery.
—— var caudata, *L. & H.*	Below New Mine Coal	Adderley Green.
Eremopteris artemisiæfolia, *Sternb.*	Doubtfull	Fenton.
Linopteris Münsteri, *Eichw.*	Peacock Marl	Marl Pit, Fenton Low.
	Knowles Rock	Gt. Fenton Colliery.
—— obliqua, *Bunb.*	Roof of Peacock Coal	Glebe Colliery.
	Great Row Rock	Longton.
	Chalky Mine Ironstone	Fenton.

* Basal Limestone. † 10 yards above Bassey Mine Ironstone. ‡ ? in Top Red Mine.

SPECIES.	HORIZON.	LOCALITY.
PLANTÆ—*continued.*		
ariopteris muricata, *Schloth.*	General from above Ash Coal	General.
	16 yds. above Moss Coal	Florence Colliery.
	Moss Coal	Longton, Fenton.
	Between Moss and Holly Lane Coals	Longton, Fenton.
	Below Bowling Alley Coal	Sneyd Colliery.
	Holly Lane Coal roof	Bucknall.
	20 yds. below Hard Mine Coal	Sneyd Colliery.
—— *forma* nervosa, *Brongn.*	Gt. Row Coal Rock	Gt. Fenton Collieries.
	Great Row Coal roof	Longton.
	Bay Coal	Longton.
	Knowles Ironstone	Gt. Fenton Collieries.
	Doubtful	Sheldon Colliery.
	Bowling Alley Rock	Adderley Green.
	2 yds. below Hard Mine Coal	Weston Coyney Colliery.
Neuropteris gigantea, *Sternb.*	Peacock Marl	Berry Hill.
	Gt. Row Coal Rock	Fenton, Longton.
	Below Little Cannel Row Coal	Clanway Colliery.
	12 yds. above Twist Coal	Chell Colliery.
	Bowling Alley Rock	Weston Coyney Colliery.
	Below Bowling Alley Coal	Sneyd Colliery.
	Holly Lane Coal	Bucknall.
	2 yds. below Hard Mine Coal	Weston Coyney Colliery.
—— heterophylla, *Brongn.*	Gt. Row Coal Rock	Longton, Fenton.
	Below Little Cannel Row Coal	Clanway Colliery.
	3 yds. above Burnwood Ironstone	Chell Colliery.
	12 yds. above Twist Coal	" "
	Bowling Alley Rock	Weston Coyney Colliery.
	Holly Lane Coal roof	Bucknall.
	Above Hard Mine Coal	Bucknall and Adderley Green Colliery.
	2 yds. below Hard Mine Coal	Weston Coyney Colliery.
	7 yds. " " "	Sneyd Colliery.
	12 yds. below 7 ft. Bambury Coal	Sneyd Colliery.
—— obliqua, *Brongn.*	12 yds. above Twist Coal	Chell Colliery.
—— plicata, *Sternb.*	Gt. Row Coal Rock	Longton Hall Colliery.
—— rarinervis, *Bunb.*	Peacock Marl	Berry Hill Colliery.
	Gt. Row Coal Rock	Longton.
	Below Little Cannel Row Coal	Clanway Colliery.
	Knowles Rock	Longton.
	Knowles Ironstone	Fenton.
—— Scheuchzeri, *Hoffm.*	Gt. Row Coal Rock	Longton.
	Knowles Ironstone	Gt. Fenton Colliery.
—— tenuifolia, *Schloth.*	Doubtfull	Fenton.
	Bowling Alley Coal roof	Birchenwood Colliery.
	Below Bowling Alley Coal	Sneyd Colliery.
Pecopteris Miltoni, *Artis*	Shales over Peacock Marl.	Longton.
	Between Moss and Holy Lane Coal	Longton, Fenton.
—— ? Volkmanni, *Sauv.*	Moss Coal	Longton, Fenton.
Renaultia schatzlarensis, *Sternb.*	"	"
Sphenopteris furcata, *Brongn.*	10 Yds below Ten Feet Coal	No. 18, Pit Birchenwood Colliery.
—— communis, *Lesq.*	Below Moss Coal	Fenton.
—— grandifrons, *Sauv.*	Gt. Row Coal Rock	Longton, Fenton.
	Gt. Row Coal roof	Longton.
	Chalky Mine Ironstone	Fenton.
—— latifolia, *Brongn.*	12 yds above Twist Coal	Chell Colliery.
—— ? multifirda, *L. & H.*	20 yds below Hard Mine Coal	Sneyd Colliery.
—— obtusiloba, *Brongn.*	Bowling Alley Rock	Weston Coyney Colliery.
	2 yds below Hard Mine Coal	" "
—— polyphylla, *L. & H.*	Knowles Rock	Thomsons Marl Pit Fenton Park.
—— ? spinosa, *Göpp.*	Ten Feet Coal	Rail-cutting, Scot Hay.
EQUISETACEÆ.		
Annularia radiata, *Brongn.*	Below Holly Lane Coal	Sneyd Colliery.
	20 yds below Hard Mine Coal	
Calamatina approximata, *Brongn.*	Gt. Row Coal Rock	Fenton.
—— undulata, *Sternb.*	16 yds above Moss Coal	Florence Colliery.
—— varians, *Sternb.*	40 yds below Little Row Coal	Clanway Colliery.
	Knowles Ironstone	Fenton.
	Holly Lane Coal	Bucknall.
	Doubtful	Adderley Green.

SPECIES.	HORIZON.	LOCALITY.
PLANTÆ—*continued.*		
Calamocladus charæformis, *Sternb.*	20 yds. below Hard Mine Coal	Sneyd Colliery.
—— equisetiformis, *Schloth.*	Gt. Row Coal Rock	Fenton.
	Below Little Cannel Row Coal	Clanway Colliery.
	Knowles Ironstone	Longton.
	Bay Coal	,,
	Bowling Alley Rock	Weston Coyney Colliery.
	20 yds. below Hard Mine Coal	Sneyd Colliery.
Eucalamites ramosus, *Artis*	Gt. Row Coal Rock	Gt. Fenton Colliery.
Pinnularia columnaris, *Artis*	General	General.
	12 yds. below 7 ft. Bambury Coal	Sneyd Colliery.
Stylocalamites Cisti, *Brongn.*	Bowling Alley Rock	Weston Coyney Colliery.
	2 yds. below Hard Mine Coal	,, ,, ,,
—— Suckowi, *Brongn.*	Below Little Cannel Row Coal	Clanway Colliery.
	Common above Ash Coal	Longton, etc.
	Bowling Alley Rock	Weston Coyney Colliery.
	Roof of Holly Lane Coal	Bucknall.
	2 yds. below Hard Mine Coal	Weston Coyney Colliery.
SPHENOPHYLLACEÆ.		
Sphenophyllum cuneifolium, *Brongn.*	Peacock Marl	Fenton.
	Gt. Row Coal Rock	Longton.
	Bay Coal	,,
	Knowles Rock	Gt. Fenton Colliery.
	18 yds. below Hard Mine Coal	Sneyd Colliery.
—— —— var. saxifragæfolium, *Sternb.*	Gt. Row Coal Rock	Gt. Fenton Colliery.
	2 yds. below Hard Mine Coal	Weston Coyney Colliery.
	7 yds. below Hard Mine Coal	Hollinswood Colliery.
—— majus, *Bronn*	Between Moss and Holly Lane Coals	Longton, Fenton.
	Hard Mine Coal roof	Adderley Green.
LYCOPODIACEÆ.		
Bothrodendron minutifolium, *Boulay*	18 yds. below Hard Mine Coal	Sneyd Colliery.
Lepidodendron aculeatum*, *Sternb.*	Gt. Row Coal Rock	Fenton.
	Ash Coal roof	Florence Colliery.
	Below Holly Lane Coal	Adderley Green.
	18 yds. below Hard Mine Coal	Sneyd Colliery.
	18 yds. below New Mine Rock	,, ,,
—— obovatum*, *Sternb.*	Bowling Alley Rock	Weston Coyney Colliery.
—— ophiurus*, *Brongn.*	Peacock Marl	Berry Hill.
	Gt. Row Coal Rock	Gt. Fenton Colliery.
	Chalky Mine Ironstone	Fenton.
—— rimosum, *Sternb.*	Doubtful	Meir Hay Colliery.
—— ? serpentigerum, *König*	Knowles Ironstone	Fenton.
Lepidophloios sp.	Little Mine Ironstone	Longton.
Lepidophyllum intermedium, *L. & H.*	Below 8 feet Bambury Coal	Hayes Wood Colliery.
—— lanceolatum, *L. & H.*	2 yds. below Hard Mine Coal	Weston Coyney Colliery.
—— triangulare, *Zeiller*	Peacock Marl	Berry Hill.
Lepidostrobus variabilis, *L. & H.*	Measures above Ash Coal	Longton.
—— allied to Geinitzi, *Schimper*	Below Gin Mine Coal	Nettle Bank Colliery.
Sigillaria Brardi, *Brongn.*	Shales above Peacock Marl	Copes Marl Pit, Longton.
	Gt. Row Coal Rock	Longton Hall Colliery.
—— camptotænia, *Wood*	Shale over Ash Ironstone	Fenton.
—— discophora, *König*	Gt. Row Coal Rock	Gt. Fenton Colliery.
	Knowles Ironstone	Longton; Gt. Fenton Colliery.
	Little Mine Ironstone	Longton.
	12 yds. below New Mine Coal	Adderley Green Colliery.
—— ichthyolepis, *Sternb.*	Peacock Marl	Gt. Fenton & Glebe Coll.
—— rugosa, *Brongn.*	Shale over Yard Coal	Fenton.
—— Sauveuri, *Zeiller*	Gt. Row Coal Rock	Longton Hall Colliery.
—— scutellata, *Brongn.*	Peacock Marl	Fenton.
—— tenuis, *Achep.*	Moss Coal	Longton.
—— tesselata, *Brongn.*	Gt. Row Coal Rock	Gt. Fenton Colliery.
	Sandst, below New Mine Coal	Longton.
	Two Row Coal roof	Leycett.
	85 yds. below Hard Mine Coal	Sneyd Colliery.
	12 yds. below New Mine Coal	Adderley Green.
	Silver Mine Coal	Brown Lees Colliery.
Stigmaria ficoides, *Sternb.*	Gt. Row Coal Rock, &c.	,, ,,
	2 yds. below Hard Mine Coal	Weston Coyney Colliery
	12 yds. below New Mine Coal	Adderley Green Colliery.

* All these species are common in the measures between the Ash and Bassey Mine Coal.

SPECIES.	HORIZON.	LOCALITY.
PLANTÆ—*continued.*		
CORDAITEÆ.		
Artisia transversa, *Artis*	Doubtful	Sneyd Colliery.
Cardiocarpus Gutbieri, *Geinitz*	Ash Coal	Glebe Colliery.
Cordaites borassifolius, *Sternb.*	Shale below Little Cannel Row	Clanway Colliery.
	Bowling Alley Rock	Weston Coyney Colliery.
	12 yds. below New Mine Coal	Longton.
ANIMALIA.		
ECHINODERMATA.		
CRINOIDEA.		
Crinoid ossicles	Below Gin Mine Coal	Nettle Bank Colliery.
ECHINOIDEA.		
Archæocidaris sp.	Below Gin Mine Coal	Nettle Bank Colliery
ANNELIDA.		
Spirorbis pusillus, *Mart.*	Common on many horizons	General.
	Limestone above Bowling Alley Coal	Rail-cutting and No. 8 Shaft, Adderley Green Colliery.
—— helicteres, *Salter*	Shale over Bowling Alley Coal	Sneyd, Ubberley, Park Hall and Whitfield Collieries.
	Shale over Magpie Coal	Brown Lees Colliery.
	Shale over Top Two Row Coal	Birchenwood Colliery.
	Shale over Tachen-end Coal	Silverdale Colliery.
ARTHROPODA.		
Beyrichia arcuata, *Bean*	Brown Mine Ironstone	Rail-cutting, Whitfield Colliery.
	Shale over Little Mine Coal	Brownfield Colliery.
	Hard Mine Coal	Adderley Green.
	Shale over Ironstone Coal	Falls Colliery.
Carbonia fabulina, *J. & K.*	Knowles Ironstone	Longton and Fenton
—— *var. Angulata, J. & K.*	” ”	” ” ”
—— bairdiodes, *J. & K.*	” ”	” ” ”
—— pungens, *J. & K.*	” ”	” ” ”
—— rankiniana, *J. & K.*	” ”	” ” ”
Dithyrocaris testudinea, *Scouler*	27ft. above 7 ft. Bambury Coal	Leycett, Birchenwood and Hayeswood Collieries.
Belinurus trilobitoides, *Buckl.*	Nodule over Hard Mine Coal	Bentilee Colliery.
Euphoberia ferox, *Salter*	Doubtful	Spoil-heap, Woodshutts Colliery.
Lithomantis carbonaria, *H. Woodw.*	Peacock Marl	Oldfield Marl Pit, Fenton.
BRACHIOPODA.		
Athyris ambigua, *Sow.*	Below Gin Mine Coal	Nettle Bank Colliery.
Chonetes laguessiana, *de Kon.*	” ” ”	” ” ”
	Below Gin Mine Coal	Speedwell Colliery.
	Below Gin Mine Coal	Florence Colliery.
Discina nitida, *Phill.*	Bay Coal roof	Foley and Chell Collieries.
	Below Gin Mine Coal	Nettlebank Collieries.
	Doubtful	Marl Pit, Weston Sprink
	Four Feet Coal roof	Upper House, Werrington

SPECIES.	HORIZON.	LOCALITY.
BRACHIOPODA—*continued.*		
Lingula mytiloides, *Sow.*	Lady Coal roof	Chell Colliery.
	Below Gin Mine Coal*	Florence Colliery.
	Below Gin Mine Coal*	Nettle Bank Colliery.
	Above Moss Coal	Longton Hall Colliery.
	17 yds. below Moss Coal	Sneyd, Florence and Berry Hill Collieries.
	Near Four Feet Coal	Silverdale Colliery.
	Doubtful	Marl Pit, Weston Sprink.
	Above 7 ft. Bambury Coal	Leycett and Hayeswood Pits.
	Four Feet Coal roof	Eaves Lane, Wetley Moor.
	Below Gin Mine Coal	Nettle Bank Colliery.
Orthis sp.	Below Gin Mine Coal	Speedwell Colliery.
Productus semireticulatus, *Mart.*	Below Gin Mine Coal	Nettle Bank Colliery.
Spirifera sp.	Below Gin Mine Coal	Speedwell Colliery.
LAMELLIBRANCHIATA.		
Anthracomya Adamsi, *Salter*	Burnwood Ironstone	Pitts Hill and Foley Collieries.
— — var. expansa, *Hind*	Ironstone in Upper Band	Gt. Fenton Colliery.
—— dolobrata, *Sow.*	With A. Adamsi	" "
	Ten Feet Coal roof	Bucknall.
—— lanceolata, *Hind*	Holly Lane Coal roof	Adderley Green Colliery.
—— minima, *Ludwig*	Doubtful	Spoil heap, Glebe Colliery.
	Knowles Ironstone	Longton, rail-cutting south of Kidsgrove.
— — var. carinata, *Hind*	" "	
—— modiolaris, *Sow.*	Ten Feet Coal roof	Adderley Green Colliery.
	Holly Lane Coal roof	" " "
	Hard Mine Coal roof	" " "
—— obovata, *Hind*	" " " "	Adderley Green and Mossfield Collieries.
—— Phillipsi, *Will.*	Little Row Coal	Clanway Colliery.
	Gubbin Ironstone	Shelton.
	Gt. Row Coal	Longton.
	Knowles Ironstone	Fenton.
	Brown Mine Ironstone	Silverdale and Whitfield rail-cutting.
—— pulchra, *Hind*	New Mine Ironstone	Pitts Hill, New Chapel, Goldenhill.
—— pumila, *Salter*	Knowles Ironstone	Fenton.
—— senex, *Salter*	Hard Mine Coal roof	Adderley Green Colliery.
	Cockshead Ironstone	Hulme Bank and Adderley Green Collieries.
—— subcentralis, *Salter*	Hard Mine Coal roof	Adderley Green Colliery.
	Cockshead Rock	Hulme and Adderley Green Colliery.
	Cockshead Ironstone	Hulme and Adderley Green Colliery.
—— Wardi, *Eth.*	Little Mine Ironstone	Chell and Gt. Fenton Collieries.
	Bowling Alley Coal roof	Adderley Green and Bucknall Colliery.
	Holly Lane Coal roof	Adderley Green and Bucknall Colliery.
	Cockshead Coal roof	Adderley Green and Mossfield Colliery.
—— Williamsoni, *Brown*	Hard Mine Coal roof	Adderley Green Colliery.
— — var. obtusa, *Ludw.*	With A. Williamsoni	" " "
Carbonicola acuta, *Sow.*	Yard Coal roof†	Chesterton.
	17 feet below Birches Coal	Florence Colliery.
	Stony Eight Feet Coal roof	Silverdale.
	Bed over Ten Feet Coal	General.
	Bowling Alley Coal roof	Bucknall and Sneyd Collieries.
	Holly Lane Coal roof	Bucknall and Sneyd Collieries.
	Above Cockshead Coal	General.
	Newpool Coal	Biddulph.
	Bambury Coal roof	Bucknall and Sneyd Collieries.
	Shale over Four Feet Coal	Upper House, Werrington, Eaves Lane and brook near Ash Hall.

* For these horizons see pp. 318–20.

† This is a local name in the Chesterton area given to the Peacock Coal.

SPECIES.	HORIZON.	LOCALITY.
LAMELLIBRANCHIATA—*continued.*		
Carbonicola acuta var. rhomboidalis, *Hind*	Cockshead Coal	Adderley Green Colliery.
	Above Moss Coal	Longton Hall Colliery.
—— aquilina, *Sow.*	Ten Feet Coal roof	Mossfield Colliery.
	Below Birches Coal	Florence Colliery.
	Bowling Alley Coal roof	Adderley Green Colliery.
	Holly Lane Coal roof	,, ,, ,,
	Hard Mine Coal roof	Mossfield, Hulme, Adderley Green and Birchenwood Collieries.
	Over Ironstone Coal	Falls Colliery, Bradley Green.
	Over Four Feet Coal	Wetley Moor, brook near Ash Hall.
—— cuneiformis, *Hind*	Hard Mine Coal roof	Bucknall.
—— gibbosa, *Hind*	Shale over Moss Coal	Longton Hall Colliery.
—— nucularis, *Hind*	Hard Mine Coal roof	Adderley Green Colliery.
	Bambury Coal roof	Talk o' th' Hill Colliery.
—— obtusa *Hind*	60 feet above Moss Coal	Longton Hall Colliery.
	Five Feet Coal roof	Silverdale.
	Ten Feet Coal	Sneyd Colliery.
	Bowling Alley Rock	Hulme Bank Colliery.
	Cockshead Rock	,, ,,
—— ovalis, *Martin*	Cockshead Ironstone roof	Adderley Green Colliery.
	Doubtful	Spoilheap, Meir Hay Colliery.
—— robusta, *Martin*	Moss Coal roof	Longton.
	Shale above Ten Feet Coal	Sneyd Colliery.
	Bowling Alley Coal	Hanley and Bucknall, Sneyd and Talk o' th' Hill Collieries.
	Holly Lane Coal	Hanley and Bucknall, Sneyd and Talk o'th'Hill Collieries.
	Ten Feet Bambury Coal	Sneyd Colliery.
	Shale over Little Mine Coal	Footrail, Bentilees.
	Above Ironstone Coal	Bradley Green Colliery.
	Cannel below Cockshead Coal	Mossfield Colliery.
—— similis, *Brown*	Ironstone band	Brook nr. Ubberley Colliery.
	Bambury Coal roof	Bucknall.
	Cockshead Rock	Hulme Bank Colliery.
	Doubtful	Spoilheap Meir Hay.
—— sub-constricta, *Sow.*	Hard Mine Coal	Mossfield and Hulme Bank Collieries.
—— sub-rotunda, *Brown*	Moss Coal roof	Adderley Green and Longton Hall Collieries.
	Bambury Coal roof	Adderley Green and Longton Hall Collieries.
— turgida, *Brown*	Above Moss Coal	Longton Hall Colliery.
	Shale below Moss Coal	Sneyd Colliery.
	Five Feet Coal roof	Silverdale.
	Above Ironstone Coal	Bradley Green Colliery.
	Bambury Coal roof	,, ,, ,,
—— Vinti, *Hind*	Priorsfield Ironstone	Longton.
Ctenodonta lævirostrum, *Portl.*	Below Gin Mine Coal	Speedwell Colliery.
—— undulata, *Phill.*	,, ,, ,,	Nettle Bank Colliery.
Edmondia rudis, *M'Coy*	,, ,, ,,	Speedwell Colliery
Myalina compressa, *Hind*	7 yds. below Moss Coal	Sneyd and Berry Hill Collieries.
	Doubtful	Marl Pit, Weston Sprink.
Naiadites carinata, *Sow.*	Knowles Ironstone	Longton, Fenton.
	Moss Coal roof	Adderley Green.
	Ten Feet Coal roof	,, ,,
	Holly Lane Coal roof	,, ,,
	9 ft. above Hard Mine Coal	Bunkers Hill Colliery.
	Hard Mine Coal roof	Adderley Green.
	Bambury Coal roof	,, ,,
—— elongata, *Hind*	Knowles Ironstones	Fenton.
—— modiolaris, *Sow.*	,, ,,	,,
	Brown Mine Ironstone	Silverdale.
	Moss Coal	Fenton, Adderley Green.
	Bowling Alley Coal roof	Hanley & Bucknall Colliery.
	Holly Lane Coal	Adderley Green and Bucknall Colliery.
	Hard Mine Coal roof	Adderley Green and Bucknall Colliery.
	Shale above Little Mine Coal	Bentilee.
	Cockshead Coal roof	Adderley Green and Mossfield Colliery.
	Bullhurst Coal roof	Halmerend.

SPECIES.	HORIZON.	LOCALITY.
LAMELLIBRANCHIATA—*continued.*		
Naiadites quadrata, *Sow.*	Knowles Ironstone	Gt. Fenton Collieries.
	Little Mine Ironstone	" "
	Ten Feet Coal roof	Adderley Green Colliery.
	Bowling Alley Coal roof	" " "
	Hard Mine Coal roof	" " "
	Cockshead Coal roof	Adderley Green and Mossfield Colliery.
—— triangularis, *Sow.*	Ten Feet Coal roof	Mossfield Colliery.
	Bowling Alley Coal roof	" "
	Hard Mine Coal roof	" "
Nucula gibbosa, *Flem.*	Below Gin Mine Coal	Speedwell Colliery.
Nuculana acuta, *M'Coy*	" " " "	" "
	18 yds. below Gin Mine Coal	Florence Colliery.
—— Sharmani, *R. Eth. Junr.*	Below Gin Mine Coal	Nettle Bank Colliery.
Posidoniella lævis, *Brown*	Below Gin Mine Coal	" " "
	Rider Coal roof	Leycett Colliery.
	27 ft. above 7 ft. Bambury Coal	" "
	Four Feet Coal	Eaves Lane, Wetley Moor.
—— sulcata, *Hind*	Below Gin Mine Coal	Nettle Bank Colliery.
Pseudamusium fibrillosum, *Salter*	" " "	" " "
Pterinopecten carbonarius, *Hind*	" " "	" " "
—— papyraceus, *Goldf.*	Bay Coal roof	Foley Colliery.
	Below Gin Mine Coal	Speedwell and Nettle Bank Collieries.
	Doubtful	Marl Pit, Weston Sprink.
	27 ft. above 7 ft. Bambury Coal	Minnie, Hayeswood, Leycett, Sneyd Coll.; Spoil-heap, Talk o' th' Hill.
	Below Winpenny Coal	E.side, Knypersley Reservoir.
	Four Feet Coal	Eaves Lane, Wetley Moor, &c.
Schizodus antiquus, *Hind*	Below Gin Mine Coal	Nettle Bank Colliery.
	" " "	Speedwell Colliery.
	Four Feet Coal	Upper House, Werrington.
Scaldia minuta, *Hind*	Doubtful	Marl Pit, Weston Sprink.
Solenomya primæva, *Phill.*	Below Gin Mine Coal	Speedwell Colliery.
Syncyclonema carboniferum, *Hind*	" " "	Nettle Bank and Speedwell Collieries.
GASTEROPODA.		
Bellerophon Dumonti, *d'Orb.*	Below Gin Mine Coal	Speedwell Colliery.
Euphemus Urei, *Flem.*	" " "	Nettle Bank Colliery.
Loxonema sp.	" " "	" " "
Macrochilina sp.	" " "	" " "
Naticopsis consimilis, *De Kon.*	" " "	" " "
Raphistoma radians, *De Kon.*	" " "	" " "
	18 yds. below Gin Mine Coal	Florence Colliery.
Turbonellina formosa, *De Kon.*	Below Gin Mine Coal	Nettle Bank Colliery.
CEPHALOPODA.		
Dimorphoceras Gilbertsoni, *Phill.*	Below Gin Mine Coal	Nettle Bank Colliery.
—— Looneyi, *Phill.*	Bed over Bay Coal	Foley Colliery.
Ephippioceras bilobatum, *Sow.*	Below Gin Mine Coal	Nettle Bank Colliery.
Gastrioceras Listeri, *Mart.*	Bed over Bay Coal	Foley Colliery.
—— carbonarium, *Von Buch*	Below Gin Mine Coal	Nettle Bank Colliery.
Glyphioceras diadema, *Beyrich*	" " "	Nettle Bank Colliery.
—— paucilobum, *Phill.*	29 ft. above 7 ft. Bambury Coal	Leycett and Minnie Collieries, Spoilheap Talk o' th' Hill.
—— micronotum, *Phill.*	Below Gin Mine Coal	Nettle Bank Colliery.
—— Phillipsi? *Foord & Crick*	" " "	" " "
—— reticulatum, *Phill.*	" " "	" " "
Pleuronautilus armatus, *J. de C. Sow*	Doubtful	Marl Pit, Weston Sprink.
—— n. sp.	Below Gin Mine Coal	Nettle Bank Collery.
Orthoceras sulcatum, *M'Coy*	" " "	Speedwell Colliery.
	" " "	Nettle Bank Colliery.
	18 yds. below Gin Mine Coal	Florence Colliery.
Stroboceras sulcatum, *Sow.*	Below Gin Mine Coal	Nettle Bank Colliery.

SPECIES.	HORIZON.	LOCALITY.
PISCES.		
ELASMOBRANCHII.		
I.—ACANTHODII.		
Acanthodes Wardi, *Egert.*	General	Longton Fenton.
—— major, *Davis*	Knowles Ironstone	Fenton.
Acanthodopsis microdon, *Traq.*	Deep Mine Ironstone	Longton.
—— Wardi, *H. & A.*	" " "	"
II.—ICHTHYOTOMI.		
Diplodus equilateralis, *Ward*	Deep Mine Ironstone	Longton.
—— gibbosus, *Agass.*	" " "	"
	Chalky Mine Ironstone	Fenton.
	Rag Mine Ironstone	"
	Knowles Ironstone	"
	Gold Mine Ironstone	"
	Four Feet Coal	Wetley Moor.
—— tenuis, *A. S. Woodw.*	Deep Mine Ironstone	Longton.
Pleuracanthus alatus, *Davis*	" "	"
	Knowles Ironstone	Longton, Kidsgrove.
	Brown Mine Ironstone	Silverdale.
—— cylindricus, *Agass.*	Chalky Mine Ironstone	Fenton.
	Rag Mine Ironstone	"
	Knowles Ironstone	"
—— lævissimus, *Agass.*	Deep Mine Ironstone	"
	Chalky Mine Ironstone	"
	Rag Mine Ironstone	"
	Knowles Ironstone	Longton, Fenton.
	Ironstone above Ash Coal	Longton.
—— robustus, *Davis*	Deep Mine Ironstone	"
	Knowles Ironstone	"
	Brown Mine Ironstone	Silverdale, Kidsgrove.
—— Wardi, *Davis*	Rag Mine Ironstone	Fenton.
	Knowles Ironstone	"
	Chalky Mine Ironstone	"
III.—SELACHII.		
C allopristodus pectinatus, *Agass.*	Deep Mine Ironstone	Longton.
	Chalky Mine Ironstone	"
	Rag Mine Ironstone	"
	Knowles Ironstone	"
Ctenoptychius apicalis, *Agass.*	Deep Mine Ironstone	Longton, Fenton.
	Chalky Mine Ironstone	" "
	Rag Mine Ironstone	Fenton.
	Knowles Ironstone	Longton, Fenton
	Brown Mine Ironstone	Silverdale.
	Gold Mine Ironstone	"
	Ash Coal	Longton, Fenton
Helodus simplex, *Agass.*	Chalky Mine Ironstone	Fenton.
	Knowles Ironstone	Longton.
	Brown Mine Ironstone	Silverdale.
	Shale over Ash Coal	"
	Cockshead Coal	Adderley Green Colliery
	Four Feet Coal	Badderley Edge.
Janassa linguæformis, *Atthey*	Deep Mine Ironstone	Longton.
Orodus sp.	Below Gin Mine Coal	Nettle Bank Colliery.
Pleuroplax Attheyi, *Barkas*	Deep Mine Ironstone	Longton.
—— Rankinei, *H. & A.*	Knowles Ironstone	"
	Shale over Hard Mine Coal	Adderley Green Colliery.
	Over Cockshead Coal	" " "
Sphenaaenthus hybodoides, *Egert.*	Chalky Mine Ironstone	Fenton.
	Knowles Ironstone	Longton.
	Shale over Ash Coal	Fenton.
	Below Gin Mine Coal	Nettle Bank Colliery.
	Cockshead Ironstone	Adderley Green Colliery.
IV.—ICHTHYODORULITES.		
Edestus triserratus, *E. T. Newton*	Below Gin Mine Coal	Nettle Bank Colliery.
Gyracanthus formosus, *Agass.*	Chalky Mine Ironstone	Fenton.
	Knowles Ironstone	Longton, Fenton.
	Brown Mine Ironstone	Silverdale.
	Shale over Ash Coal	Longton.
	Cockshead Coal	Adderley Green Colliery.
Listracanthus Wardi, *A. S. Woodw.*	Below Gin Mine Coal	Nettle Bank Colliery.

SPECIES.	HORIZON.	LOCALITY.
PISCES—*continued.*		
V.—INCERTÆ SEDIS.		
Euctenius unilateralis, *Barkas* -	Gubbin Ironstone -	Shelton.
	Deep Mine Ironstone	Longton, Fenton.
	Knowles Ironstone -	" "
	Moss Coal -	Florence Colliery.
	Hard Mine Coal shale	Adderley Green Colliery.
Stemmatodus sp. -	Deep Mine Ironstone	Longton.
	Rag Mine Ironstone	Fenton.
	Below Gin Mine Coal	Nettle Bank Colliery.
DIPNOI.		
Ctenodus cristatus, *Agass.* -	Knowles Ironstone -	Longton, Fenton.
Murchisoni, *Ward*	Brown Mine Ironstone -	Silverdale.
Sagenodus inequalis, *Owen* -	Deep Mine Ironstone	Longton.
	Ten Feet Coal roof -	Adderley Green Colliery.
—— quinquecostatus, *Traq.*	Knowles Ironstone	Fenton.
TELEOSTOMI.		
I.—CROSSOPTERYGII.		
Cœlacanthus elegans, *Newb.*	General -	General.
Megalichthys coccolepis, *Young*	Deep Mine Ironstone	Fenton.
	Knowles Ironstone -	"
	Rag Mine Ironstone	"
	Cockshead Ironstone	Adderley Green.
—— Hibberti, *Agass.*	Gubbin Ironstone -	Shelton.
	Knowles shales -	Longton, Fenton.
	Brown Mine Ironstone -	Silverdale.
	Above Ironstone Coal -	Falls Colliery.
	Cockshead Ironstone	Adderley Green.
	Four Feet Coal -	Wetley Moor, Badderley Edge.
—— intermedius, *A. S. Woodw.* -	Deep Mine Ironstone	Longton, Fenton.
	Knowles Ironstone -	" "
	Ash Coal Ironstone -	" "
	Below Gin Mine Coal	Nettle Bank Colliery.
—— pygmæus, *Traq.*	Muck Row Coal -	Bradley green.
	Hard Mine Coal	Adderley Green Colliery.
	Ironstone Coal -	Bradley Green.
	Four Feet Coal -	Badderley Edge.
—— rugosus, *Young*	Knowles Ironstone -	Longton.
	Ash Coal shale -	"
Rhizodopsis sauroides, *Will.*	General -	General.
	Deep Mine Ironstone	Longton.
Strepsodus sauroides, *Binney*	Chalky Mine Ironstone -	Fenton.
	Knowles Ironstone -	"
	Brown Mine Ironstone	Silverdale.
	Gold Mine Ironstone -	"
	Over Ash Coal -	Fenton.
II.—ACTINOPTERYGII.		
Cheirodus granulosus, *Young*	Deep Mine Ironstone	Longton, Fenton.
	Chalky Mine Ironstone	" "
	Knowles Ironstone -	" "
	Brown Mine Ironstone -	Silverdale.
	Shale over Ash Ironstone	Longton.
	Cockshead Coal -	Adderley Green Colliery.
Cycloptychius carbonarius, *Young*	Deep Mine Ironstone	Longton, Fenton.
Elonichthys Aitkeni, *Traq.* -	Bullhurst Coal roof	Foot-rail near Hulme Dale.
—— Egertoni, *Agass.* -	Doubtful -	Silverdale.
	Deep Mine Ironstone	Longton, Fenton.
—— caudalis, *Traq.* -	Knowles Ironstone -	Fenton.
—— microlepidotus, *Traq.* -	" "	"
—— oblongus, *Traq.* -	" "	"
—— semistriatus, *Traq.*	" "	"
—— sp. -	Four Feet Coal -	Eaves Lane, Wetley Moor.
Eurylepis anglica, *Traq.* -	Shale over Ash Coal -	Longton.
Gonatodus Molyneuxi, *Traq.*	Deep Mine Ironstone	Longton.
Mesolepis scalaris, *Young* -	Knowles Ironstone -	Longton, Fenton.
	Cockshead Ironstone	Adderley Green.
—— Wardi, *Young*	Knowles Ironstone -	Longton, Fenton.
	Shale over Ash Coal -	Longton.
Platysomus parvulus, *Agass.*	Chalky Mine Ironstone	Longton, Fenton.
	Knowles Ironstone -	" "
	Brown Mine Ironstone	Silverdale.
	Cockshead Coal	Adderley Green Colliery.
—— Fosteri, *H. & A.*	Doubtful -	Newstead Boring.

SPECIES.	HORIZON.	LOCALITY.
PISCES—*continued.*		
Rhadinichthys macrodon, *Traq.*	Knowles Ironstone	Fenton.
—— monensis, *Egert.*	Deep Mine Ironstone	Longton Hall Colliery.
	Doubtful	Marl Pit, Weston Sprink.
	Bay Coal	Longton.
	Shale over Ash Coal	"
	Four Feet Coal	Upper House, Werrington.
—— Planti, *Traq.*	Deep Mine Ironstone	Longton.
	Shale over Ash Coal	"
—— Wardi, *Young*	" " "	"
AMPHIBIA.		
LABYRINTHODONTIA.		
Anthracosaurus Russelli, *Huxley*	Rag Mine Ironstone	Fenton.
	Ash Ironstone	Longton.
Keraterpeton Galvani. *Huxley*	Shale over Ash Coal	Longton Hall Colliery.
Loxomma Allmanni, *Huxley*	Gubbin Ironstone	Shelton.
	Chalky Mine Ironstone	Fenton.
	Knowles Ironstone	Shelton, Fenton.
	Ash Ironstone	Fenton.
Pteroplax cornuta, *A. & H.*	Knowles Ironstone	Fenton.

APPENDIX No. II.

Tables shewing the distribution of the Chief Fossils in relation to the Marine Beds of the Coal Measures.

NOTE.—These Tables are compiled from the List given in Appendix No. I. The exact position of the marine horizons in association with the Coal seams which are lettered in italics, will be found on pages (47-50). The marine bed overlying the Bay Coal is the highest horizon at which fossils of marine habitat are met with. The distinction between the Lamellibranchiate fauna above and below this line is very marked. It will also be observed that the fish fauna shows a marked diminution above the Deep Mine Ironstone, only eight species ranging above it; and of these it may be noticed that two genera, *Cœlacanthus* and *Acanthodes* range into the Permian Rocks.

The first column includes the strata which have been known as the Upper Coal Measures; columns 2 to 7 have been regarded as forming the Middle Coal Measures, and those below have been termed Lower Coal Measures.

——	Bassey Mine Coal and above.	Intermediate measures.	Deep Mine Ironstone.	Intermediate measures.	*Bay Coal* (roof of).	Intermediate measures.	Ash Coal (roof of).	Intermediate measures.	*Gin Mine Coal* (below).	Intermediate measures.	*Moss Coal.*	Intermediate measures.	*7 ft. Banbury Coal* (27 ft. above).	Intermediate measures.	*Crabtree Coal.*
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PLANTÆ.															
FILICACEÆ															
Alethopteris aquilina, *Schloth.*	1	2	..	..		..	..	..	..	..	..	12			
———— decurrens, *Artis*	..	..	..	..	..	6									
———— lonchitica, *Schloth.*	1	2	..	..	..	6	..	..	..	..		12	13		
———— valda, *Bunb.*	1														
———— sp.			..	..	..	6									
Aphlebia ? crispa, *Gutb.*	..	..	..	..	..	..	..	..	..	..	..	12			
Dactylotheca plumosa, *Artis*	..	..	..	..	..	..	..	..		..	..	..	..	14	
———— plumosa, *var.* caudata, *L. & H.*	..	2													
Linopteris Münsteri, *Eichw.*	1	2													
———— obliqua, *Bunb.*	1	2	..	4											
Mariopteris muricata, *Schloth.*	1	2	..	..	..	..	..	..	..	10	11	12			
—— —— *forma* nervosa, *Brongn.*	..	2	..	..	5	6	..	..		..	..	12			
Neuropteris acuminata, *Schloth.*	1														
———— emarginata, *Brongn.*	1														

	Bassey Mine Coal and above.	Intermediate measures.	Deep Mine Ironstone.	Intermediate measures.	*Bay Coal* (roof of).	Intermediate measures.	Ash Coal (roof of).	Intermediate measures.	*Gin Mine Coal* (below).	Intermediate measures.	*Moss Coal.*	Intermediate.	*7 ft. Bambury Coal.* (27 ft. above).	Intermediate measures.	*Crabtree Coal.*
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PLANTÆ—*continued.*															
Neuropteris gigantea, *Sternb.*	1	2	..	..	..	..	..	8	..	..	..	12			
——— heterophylla, *Brongn.*	1	2	..	..	.	..	..	8	..	..	..	12	13*		
——— macrophylla, *Brongn.*	1														
——— obliqua, *Brongn.*	..	..	..	..	..	..	..	8							
——— ovata, *Hoffm.*	1														
——— plicata, *Sternb.*	..	2													
——— rarinervis, *Bunb.*	1	2	..	..	..	6									
——— Scheuchzeri, *Hoffm.*	1	2	..	..	..	6									
——— tenuifolia, *Sternb.*	1	2	..	..	..	..	..	.	..	..	..	12			
Odontopteris sp.	1														
Pecopteris arborescens, *Brongn.*	1														
——— ——— *var.* cyathea, *Brongn.*	1														
——— Miltoni, *Artis*	1	2										12			
——— ? Volkmanni, *Sauv.*	..	..	..	..	..	..	..	..	..	..	11				
Renaultia schatzlarensis, *Stur.*	..	..	..	...	..	..	..	..	..	..	11				
phenopteris furcata, *Brongn.*	..	..	..	..	..	...	..	..	..	..	..	12			
——— communis, *Lesq.*	..	..	..	..	..	..	..	..	..		..	12			
——— grandifrons, *Sauv.*	1	2	..	4											
——— multifida, *L. & H.*	..	..	..	..	..	..	..	..	..	.	..	12			
——— obtusiloba, *Brongn.*	..	..	.	..	..	..	..	..	..		..	12			
——— polyphylla, *L. & H.*		..	..	..	..	6									
——— spinosa, *Göpp.*	..	..	..		..	..	..	..	..	10					
——— sp.	1														
EQUISETACEÆ.															
Annularia radiata, *Brongn.*	1	..	..	..	.	..	..		..	..	..	12			
——— galioides, *L. & H.*	1	..	..	..	..	..	..	..	..	..	..				
Calamatina approximata, *Brongn.*	1	2													
——— Schutzei, *Sternb.*	1														
——— undulata, *Sternb.*	1	..	..	..	..	..	..	..	..	10					
——— varians, *Sternb.*	1	2	..	..	..	6	.	..	..		..	12			
Calamocladus charæformis, *Sternb.*	..	..	..	..	..	..	..	..	..	..	..	12			

* 12 yards below the 7 feet. Bambury Coal.

——	Bassey Mine Coal and above.	Intermediate measures.	Deep Mine Ironstone.	Intermediate measures.	*Bay Coal* (roof of).	Intermediate measures.	Ash Coal (roof of).	Intermediate measures.	*Gin Mine Coal* (below).	Intermediate measures.	*Moss Coal.*	Intermediate measures.	*7 ft Bambury Coal* (27 feet above).	Intermediate measures.	*Cabtree Coal.*
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PLANTÆ—*continued.*															
Calamocladus equisetiformis, *Schloth.*	1	2	..	..	5	6	..	..	..	..	..	12			
Eucalamites ramosus, *Artis* -	..	2													
Macrostachya infundibuliformis, *Brongn.*	1														
Pinnularia columnaris, *Artis* -													13*		
Stylocalamites Cisti, *Brongn.* - -	1	..	..			..	..	.	..	..	..	12			
———— Suckowi, *Brongn.* -	1	2	..	.		6	..	..	..	..	..	12		14	
SPHENOPHYLLACEÆ.															
Sphenophyllum cuneifolium, *Brongn.*	1	2	..	..	5	6		..	..	..	..	12			
——— ——— *var.* saxifragæfolium, *Brongn.* -	..	2		..	..	..	.	..	..	..	..	12			
——— emarginatum, *Brongn.* -	1														
——— majus, *Brongn* - -	..	..		..	..	..	..		..	..		12			
LYCOPODIACEÆ.															
Bothrodendron minutifolium, *Boulay*	..	..	..		..	..	..	..	.	..	..	12			
Lepidodendron aculeatum, *Sternb.* -		2	..	..		..	7	..		..	..	12	.	14	
———— lycopodioides, *Sternb.*	1														
———— obovatum, *Sternb.* -	..		..	..	..	.	..	..	..		..	12			
———— ophiurus, *Brongn.* -	1	2		4											
———— serpentigerum, *König*	..	..		..	..	6									
———— Wortheni, *Lesq.*	1														
Lepidophloios sp. -	..	..	..	..		..	..	8	..	..					
Lepidophyllum intermedium, *L.& H.*	..	..	..	..	..	..	..	..	..	..	..	..	..	14	
———— lanceolatum, *L.& H.*	1	..	..	..	.	..	..	..	..	..	..	12			
———— triangulare, *Zeill.*	..	2													
Lepidostrobus anthemis, *König* -	1														
———— (?) Geinitzi, *Schimper*															
———— variabilis, *L. & H.* -	1	..	..	..	..	6									
Sigillaria Brardi, *Brongn.* -	1	2													
——— camptotænia, *Wood* - -	..	..	..	..	..	..	7								
——— discophora, *König* -	1	2	..	..	..	6	..	8	..	..	..	..	..	14	

* 12 yards below the 7 ft. Bambury Coal.

—	Bassey Mine Coal and above.	Intermediate measures.	Deep Mine Ironstone.	Intermediate measures.	*Bay Coal* (roof of).	Intermediate measures.	Ash Coal (roof of).	Intermediate measures.	*Gin Mine Coal* (below).	Intermediate measures.	*Moss Coal.*	Intermediate measures.	*7 ft. Banbury Coal* (27 ft. above).	Intermediate measures.	*Crabtree Coal.*
	1	2	3	4	5	6	7	8	9	10	11	12	31	14	15
PLANTAE—*continued.*															
Sigillaria ichthyolepis, *Sternb.*	1	2													
——— ovata, *Sauv.*	1														
——— rugosa, *Brongn.*	..	..	..	..	..	..	..	..	..	..		12			
——— Sauveuri, *Zeill.*	..	2													
——— scutellata, *Brongn.*	..	2													
——— tenuis, *Achep.*	..	..	..	..	..	..	..		..	..	11				
——— tesselata, *Brongn.*	1	2	..		..	..		8	..	..	..	12	..	14	
Stigmaria ficoides, *Sternb.*	1	2	..	..	..	..		8	..	..	..	12	..	14	
CORDAITEÆ.															
Artisia transversa, *Artis*	1	..	..		..	..	..	..	..	..	..				
Cardiocarpus Gutbieri, *Geinitz*		..	..		..	..	7								
Cordaites borassifolius, *Sternb.*	1	2	..	..	..	..	..	..	..		..	12	..	14	
——— sp.	1														
Rhabdocarpus sulcatus, *Presl.*	1														
Trigonocarpus Parkinisoni, *Brongn.*	1														
ANIMALIA.															
BRACHIOPODA.															
Athyris ambigua, *Sow.*		..	..	..	..	..	..	..	9						
Chonetes laguessiana, *de Kon.*	..	..	..	..	..	..	..	..	9						
Discina nitida, *Phill.*	..	..	..	..	5	..	..	..	9	..	..	..	..	..	15
Lingula mytiloides, *Sow.*	..	..	..	..	5	..	..	..	9	10*	11	12†	13	..	15
Orthis sp.	..	..	..	..	..	..	..	..	9						
Productus semireticulatus, *Sow.*	..	..	..	..	..	..	..	..	9						
Sprifera sp.	..	..	..	..	..	..	..	..	9						
LAMELLIBRANCHIATA.															
Anthracomya Adamsi, *Salter*	..	..	..	..	..		..	8							
——— ——— *var.* expansa, *Hind*	..	..	..	..	..		..	8							
——— dolabrata, *Sow.*	..	..	..		..	..	..	..		..	..	12			
——— minima, *Ludwig*	..	..	..	..	..	6									
——— ——— *var.* carinata, *Hind*	..	..	..	..	..	6									
——— modiolaris, *Sow.*	..	..	..	..	..		..	..		..	..	12			
——— obovata, *Hind*	..	..	..	..	..	..	..	..	..	..		12			
——— Phillipsi, *Will.*	1	2	..	..	..	6									

* In marine bed 17 yards below the Gin Mine at the Florence Colliery.
† In marine bed 30 yards below the Moss Coal.

——	Bassey Mine Coal and above.	Intermediate measures.	Deep Mine Ironstone.	Intermediate measures.	*Bay Coal* (roof of).	Intermediate measures.	Ash Coal (roof of).	Intermediate measures.	*Gin Mine Coal* (below)	Intermediate measures.	*Moss Coal.*	Intermediate measures.	*7 ft. Banbury Coal* (27 ft. above).	Intermediate measures.	*Crabtree Coal.*
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
LAMELLIBRANCHIATA—*continued.*															
Anthracomya pulchra, *Hind*	..	..	..	..	..	..		8							
———— pumila, *Salter*	..	..	..	..	..	6									
———— senex, *Salter*	..	..	..	..	..	..		..	..	..		12	..	14	
———— subcentralis, *Salter*	..	..	..	..	..	..	..	..	..	..	..	12	..	14	
———— Wardi, *Eth.* - -	..	..	..	..	..	..	..	8	..	..	..	12	..	14	
———— Williamsoni, *Brown* -	..	..	..	..	...	..	..	..	..	..	..	12			
———— *var.* obtusa, *Ludwig*-	..	..	..	..	..	..	..	..	..	..	..	12			
Carbonicola acuta, *Sow.* - -	.	2	..	..	..	..	..	..	..	..	..	12	..	14	15
———— *var.* rhomboidalis, *Hind*	..	..	..	..	..	..	..	.	..	..	..	..	..	14	
———— aquilina, *Sow.* - -	..	..	..	..	..	..	..	.	..	10	..	12	..	14	15
———— cuneiformis, *Hind* -		..	..	..	..	..	..		..	..	..	12			
———— gibbosa, *Hind* -		..	..	..	..	..	..	..	..	10					
———— nucularis, *Hind* -			..	..	..	..	..		.	..	..	12	.	14	
———— obtusa, *Hind* -	..			..	..	..	..	..		10	..	12		14	
———— ovalis, *Martin* -				..	..	..	..	..		..	..	..	..	14	
———— robusta, *Martin* - -		.		..	..	..	..	..	.	..	11	12	..	14	
———— similis, *Brown* -			..	..	..	..	..	..		..	..	..		14	
———— sub-constricta, *Sow.* -			..	..	..	..	..	..		..	..	12			
———— sub-rotunda, *Brown* -		..	..	..	..	..	..			..	11	..		14	
———— turgida, *Brown* -		.	..	..	..	..	..	.		10	..	12	.	14	
———— Vinti, *Hind* - -	1		..	..	..	6									
Ctenodonta lævirostrum, *Portl.* -			..	..	..	..	..	.	9						
———— undulata, *Phill.* -	.		..	..	..	..	..		9						
Edmondia rudis, *M'Coy* -			..	..	..	..	..		9						
Myalina compressa, *Hind* -			..	..	..	6	..			..	..	12			
Naiadites carinata, *Sow.* - -		.	..	..	..	6	.			10	..	12	..	14	
———— elongata, *Hind*- -		..	..	..	..	6									
———— modiolaris, *Sow.* -	.	..	..		..	6	..	..	..	..	11	12	..	14	
———— quadrata, *Sow.*- -			..	..	..	..	..	8	..	..	..	12	..	14	
———— triangularis, *Sow.* -	..		..	..	..	..	..	..	..	..	..	12			
Nucula gibbosa, *Flem.*	..			..	..	..	..		9						
Nuculana acuta, *M'Coy* - -	..			..	..	..	..	.	9						
———— Sharmani, *R. Eth. Jun.* -	..	..	.	..	..	..	..	..	9						
Pseudamusium fibrillosum, *Salter* -	..	..	..	..		..	..	..	9						

—	Bassey Mine Coal and above.	Intermediate measures.	Deep Mine Ironstone.	Intermediate measures.	*Bay Coal* (roof of).	Intermediate measures.	Ash Coal (roof of).	Intermediate measures.	*Gin Mine Coal* (below).	Intermediate measures.	*Moss Coal.*	Intermediate measures.	*7 ft. Bambury Coal* (27 ft. above).	Intermediate measures.	*Crabtree Coal.*
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
LAMELLIBRANCHIATA—*continued.*															
Pterinopecten papyraceus, *Goldf.*		.	..	..	5	..	..	..	9	..	..	12*	13	?	15
——— carbonarius, *Hind*		..	..	..	..	..	..	..							
Posidoniella lævis, *Brown*		..	..	..	..	..	..	..	9	..	..	..	13	..	15
——— sulcata, *Hind*		..	..	..	..	..	..	..	9						
Syncyclonema carboniferum, *Hind*		..	..	..	..	..	..	..	9						
Schizodus antiquus, *Hind*	..	..	..	..	..	..	..	..	9	..	..	..		..	15
Scaldia minuta, *Hind*	..	..	..	..	..	..		..	..		..	12*			
Solenomya primæva, *Phill.*	..	..	..	..	..	..	..	..	9						
GASTEROPODA.															
Bellerophon Dumonti, *d'Orb.*	..	..	..	..		..	..		9						
Euphemus Urei, *Flem.*	..	..		..	..	..	..		9						
Loxonoma sp.	..	..	..	..	..	..	..	..	9						
Macrochilina sp.		..	..	..	..		..	..	9						
Naticopsis consimilis, *de Kon.*		..	..		..	..		..	9						
Raphistoma radians, *de Kon.*	..		..		..	..		..	9						
Turbonellina cf. formosa, *de Kon.*	..		..	..		..	..	..	9						
CEPHALOPODA.															
Dimorphoceras Gilbertsoni, *Phil.*	..	..		..		..	..	.	9						
——— Looneyi, *Phill.*	..	..		..	5										
Ephippioceras bilobatum, *Sow.*	..	..		..	..		..	..	9						
——— costatum, *Foord*		..	..		..	..		..	9						
Gastrioceras Listeri, *Martin*	..	..	..		5										
——— carbonarium, *von Buch*	..	..	..		..	..	..	..	9						
Glyphioceras diadema, *Beyrich*	..	..	..	..	..	..	..	..	9						
——— micronotum, *Phill.*	..	..	..	..		..	..	..	9						
——— paucilobum, *Phill.*	..	..	.	..	..	..	..		..	..	..		13		
——— Phillipsi? *Foord & Crick*	..	..	.	..	..		..	..	9						
——— reticulatum, *Phill.*	.	..	..	..	..		..	..	9						
Pleuronautilus armatus, *J. de C. Sow.*	..	..	..	..	..	..		..		..	..	12*			
Orthoceras sulcatum, *M'Coy*	..	..	..	..	..	..		..	9						
Stroboceras sulcatum, *J. de C. Sow.*	..	..	..		..	..		..	9						

* At Weston Sprink, horizon doubtful. Although marine fossils and *Carbonicola* are found in the same column of the table, they never occur in the same stratum. See p. 306.

——	Bassey Mine Coal and above.	Intermediate measures.	Deep Mine Ironstone.	Intermediate measures.	*Bay Coal* (roof of).	Intermediate measures.	Ash Coal.	Intermediate measures.	*Gin Mine Coal* (below).	Intermediate measures.	*Moss Coal.*	Intermediate measures.	*7 ft. Bambury Coal* (27ft. above).	Intermediate measures.	*Crabtree Coal.*
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PISCES.															
ELASMOBRANCHII.															
Acanthodes Wardi, *Egert.*	1	2	3	4	..	6	7	..	9	..	..	..	..	14	15
——— major, *Davis*	..	..	..	..	..	6									
Acanthodopsis microdon, *Traq.*	..	.	3												
——— Wardi, *H. & A.*	..	..	3												
Callopristodus pectinatus, *Agass.*	..	..	3	4	..	6									
Ctenoptychius apicalis, *Agass.*	..	..	3	4	..	6	7								
Diplodus equilateralis, *Ward*	..	..	3												
——— gibbosus, *Agass.*	..	..	3	4	..	6	..	..	..	..	..	..	..	..	15
——— tenuis, *A. S. Woodw.*	..	..	3												
Edestus triserratus, *E. T. Newton*	.	..	..	..	..	..	..	..	9						
Euctenuis unilateralis, *Barkas*		2	3	..	..	6	7	..	.	..	11	12			
Gyracanthus formosus, *Agass.*		..	.	4	..	6	7	..	..	..	..	..	..	14	
Helodus simplex, *Agass.*		.	.	4	..	6	7		.	..	..	..	..	14	15
Janassa linguæformis, *Atthey*			3												
Listracanthus Wardi, *A. S. Woodw.*	.			..	..	..	..	..	9						
Orodus sp.	..	..	.	..	..	..	..	..	9						
Pleuracanthus alatus, *Davis*	..	..	3	..	..	6									
——— cylindricus, *Agass.*	..	..	..	4	..	6									
——— lævissimus, *Agass.*	..	..	3	4	..	6	7								
——— robustus, *Davis*		..	3	.	..	6									
——— Wardi, *Davis*	..	..	..	4	..	6									
Pleuroplax Attheyi, *Barkas*	..	..	3												
——— Rankinei, *H. & A*	..	..	..	..	..	6		.	.	..	.	12	..	14	
Sphenacanthus hybodoides, *Egert.*	..	..	..	4	..	6	7	..	9	..	..	..		14	
Stemmatodus sp.		..	3	4	..	..	..	..	9						
DIPNOI.															
Ctenodus cristatus, *Agass.*	1		..	..	..	6									
——— Murchisoni, *Ward.*	1		..	..	..	6									
Sagenodus inæqualis, *Owen*	..	.	3	..	..	..	..	..	..		..	12			
——— quinquecostatus, *Traq.*	..	..	..	..	..	6									

———	Bassey Mine Coal and above.	Intermediate measures.	Deep Mine Ironstone.	Intermediate measures.	*Bay Coal* (roof of).	Intermediate measures.	Ash Coal (roof of).	Intermediate measures.	*Gin Mine Coal* (below).	Intermediate measures.	*Moss Coal.*	Intermediate measures.	*7 ft. Bambury Coal* (27 feet above).	Intermediate measures.	*Crabtree Coal.*
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PISCES—*continued.*															
TELEOSTOMI.															
Cœlacanthus elegans, *Newb.* -	1	..	3	4	5	6	7	8	9	10	11	12	..	14	
Cheirodus granulosus, *Young* - -	..	..	3	4	..	6	7	..	..	..	..	..	..	14	
Cycloptychius carbonarius, *Young* -	..	..	3												
Elonichthys Aitkeni, *Traq.* - -	..	..	..	..	..	..	..		..	..	..	..	.	14	
——— caudalis, *Traq.* - -	..	..	..	..	..	6									
——— Egertoni, *Agass.* -	..	..	3												
——— microlepidotus, *Traq.*	..	..		..	..	6									
——— oblongus, *Traq.* - -	..			..	..	6									
——— semistriatus, *Traq.* -	..	..	..	..	..	6									
——— sp. -	..	..		..	..	..		..	..	..	..	..	..	..	15
Eurylepis anglica, *Traq.* - -	..	..	..	..	..	..	7								
Gonatodus Molyneuxi, *Traq.* - -	..	..	3												
Megalichthys coccolepis, *Young* -	..	..	3	4	..	6	..	..	..	..	..	..	..	14	
——— Hibberti, *Agass.*- -	1	2	3	4	..	6	7	..	9	..	11	12	..	14	15
——— intermedius, *A. S. Woodw.*	..	..	3	..	..	6	7		9						
——— pygmæus, *Traq.* -	..	..	..	..	..	..	..		..	..	..	12	..	14	15
——— rugosus, *Young* - -	..	..	..	..	..	6	7								
Mesolepis scalaris, *Young* -	..	..	..	.	..	6	..		..	..	..	..	..	14	
——— Wardi, *Young* - -	..	..	..	..	..	6	7								
Platysomus Forsteri, *H. & A.* -		..	3	..	..	..	..	..	..	..	11				
——— parvulus, *Agass.* -		..	..	4	..	6	..	..	9	..	..	..	..	14	
Rhadinichthys macrodon, *Traq.* -		..	..	..	..	6									
——— monensis, *Egert.* -		.	3	..	5	..	7	..	..	..	..	..	..	..	15
——— Planti, *Traq.* -		..	3	..	..	..	7								
——— Wardi, *Young* - -	..	..	..	..	..	..	7								
Rhizodopsis sauroides, *Williamson*-	1	2	3	4	..	6	7	8	9	10	11	..	13	14	15
Strepsodus sauroides, *Binney* - -	..	..	3	4	..	6	7								
AMPHIBIA.															
LABYRINTHODONTIA.															
Anthracosaurus Russelli, *Hux.* -	..	..	..	4	..	..	7								
Loxomma Allmanni, *Hux.* - -	..	2	..	4	..	6	7								
Pteroplax cornuta, *H. & A.* -	..	2	..	..	..	6									
Keraterpeton Galvani, *Hux.* -	..	..	..	..	..	..	7								

APPENDIX III.

Sections of Colliery Shafts, etc.

INDEX.

THE POTTERY COALFIELD.

SECTION No. 1.

NEWSTEAD BORING NEAR TRENTHAM.

O.D. 400 Feet.

The character of the beds down to 1,593 feet was determined by Messrs. Ward & Gibson, supplemented below this depth by the sinker's record.

From Mr. G. A. Mitcheson.

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Soil	1	0	1	0
Boulder clay with stones	9	0	10	0
Soft purple marl	4	6	14	6
Purple marl	6	0	20	6
Purple sandy marl with pieces of sandstone	12	9	33	3
Purple sandy marl with cornstone	3	10	37	1
Fine-grained purple sandstone	30	0	67	1
Purple and grey sandstone	2	7	69	8
Purple and grey sandstone, hackley grained	1	5	71	1
Soft purple marl with shot-like concretions	7	0	78	1
Soft purple marl	0	2	78	3
Soft purple sandy micaceous marl	1	0	79	3
Sandy indurated micaceous purple marl	20	9	100	0
Soft purple marl, mottled at bottom	10	0	110	0
Soft purple marl	1	0	111	0
Indurated sandy purple marl (*Pecopteris Miltoni*)	6	2	117	2
Soft purple mottled marl	5	11	123	1
Soft purple marl	14	5	137	6
Purple marl	1	6	139	0
Very sandy mottled purple marl	1	10	140	10
Purple mottled marl	4	3	145	1
Green mottled marl	2	7	147	8
Purple marl with yellow nodules	5	0	152	8
Purple marl	6	4	159	0
Purple sandy marl	2	3	161	3
Soft purple marl	5	0	166	3
Very soft bright purple marl	1	2	167	5
Grey and mottled marl	1	2	168	7
Purple and mottled marl	4	1	172	8
Soft purple marl, sandy at bottom	1	2	173	10
Soft purple marl	1	2	175	0
Indurated slightly micaceous purple marl	2	7	177	7
Purple marl	2	2	179	9
Purple sandy marl	1	7	181	4
Fine-grained sandstone	1	6	182	10
Fine-grained white sandstone	1	1	183	11
Fine red sandstone	0	10	184	9
Sandy marl	0	5	185	2
Fine-grained purple sandstone	2	1	187	3
Purple sandy marl	1	4½	188	7½
Purple marl	0	2	188	9½

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Purple sandstone with white band	4	8	193	5½
Red mottled sandstone	3	3	196	8½
Purple marl with green patches	0	3½	197	0
Fine-grained marly sandstone	1	5	198	5
Fine red sandstone	5	10½	204	3½
Purple micaceous sandstone	1	8½	206	0
Soft marl with marl nodules - -	0	2	206	2
Indurated purple sandy marl, with nodules	5	7	211	9
Purple sandy marl- -	2	3	214	0
Fine-grained purple sandstone	2	2	216	2
Soft purple marl -	0	8	216	10
Purple sandy marl with nodules	5	10	222	8
Purple marl with nodules -	5	1	227	9
Indurated sandy marl, very sandy at bottom	4	11	232	8
Fine-grained purple sandstone, passing down into mottled red marl	4	11	237	7
Purple marl - -	4	0	241	7
Fine-grained purple calcareous sandstone	1	8	243	3
Purple hard calcareous rag	0	2	243	5
Sandy marl	0	9	244	2
Indurated purple marl	3	5	247	7
Dark sandy marl with concretions - -	3	0	250	7
Dark purple sandy marl with concretions	7	11	258	6
Very soft purple marl with concretions	4	10	263	4
Very dark soft marl	5	0	268	4
Soft purple marl	4	7	272	11
Purple sandy marl-	2	5	275	4
Dark purple marl	1	0	276	4
Soft marly micaceous sandstone	3	6	279	10
Fine-grained purple micaceous sandstone	2	5	282	3
Purple marl - -	0	1	282	4
Fine-grained purple micaceous sandstone	10	10	293	2
Mottled micaceous sandstone -	5	2	298	4
Coarse micaceous purple sandstone -	0	10	299	2
Coarse micaceous purple and white sandstone	3	8	302	10
Micaceous coarse-grained purple sandstone	5	2	308	0
Micaceous fine-grained purple sandstone -	10	7	318	7
Purple sandstone with grey blotches	14	1	332	8
Purple and white sandstone	2	1	334	9
Purple sandstone -	0	11	335	8
White sandstone with purple blotches	1	4	337	0
Coarse purple sandstone- -	2	5	339	5
Purple sandstone	2	6	341	11
Highly micaceous purple flaggy sandstone	0	7	342	6
Micaceous white sandstone -	1	4	343	10
Micaceous purple sandstone	5	2	349	0
Soft purple marl	2	6	351	6
Hard marly sandstone - -	2	8	354	2
Sandy marl - -	3	10	358	0
Soft marl	1	2	359	2
Purple indurated marl -	4	4	363	6
Soft purple marl - - -	2	2	365	8
Fine-grained purple sandstone -	5	4	371	0

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Indurated purple marl	1	3	372	3
Purple sandstone	0	6	372	9
Indurated purple marl -	3	0	375	9
Soft purple marl with limestone nodules at base	1	10	377	7
Rather hard variegated marl -	0	6	378	1
Variegated soft marl	4	8	382	9
Variegated indurated marl	4	7	387	4
Purple indurated marl	15	4½	402	8½
Compact green marl with purple film at top	0	1	402	9½
Greenish-black shale	0	3	403	0½
Black bass with plants	0	0½	403	1
Very dark purple marl with plants -	0	2	403	3
Variegated and green marl with hard green marl pebbles - - -	2	4	405	7
Very hard indurated purple marl	2	8	408	3
Very sandy indurated purple marl	3	4	411	7
Soft mottled marl -	2	4	413	11
Hard purple marl	4	11	418	10
Soft purple and yellow marl -	3	2	422	0
Strong purple marl, sandy at base -	2	10	424	10
Highly micaceous purple sandstone-	5	9	430	7
Micaceous purple sandstone	2	0	432	7
Strong purple marl passing into very sandy marl	3	6	436	1
Strong purple marl with nodules - -	5	3	441	4
Soft purple marl, slightly calcareous	3	0	444	4
Hard purple marl with nodules	5	6	449	10
Soft purple marls - - - -	11	1	460	11
Very micaceous purple sandstone - -	19	4	480	3
Micaceous fine-grained purple sandstone-	5	3	485	6
Highly-micaceous coarse purple sandstone -	5	1	490	7
Hard compact purple sandstone -	2	5	493	0
Coarse purple grit with bands of cornstone -	6	4	499	4
Micaceous rather coarse purple sandstone	5	7	504	11
Coarse highly-micaceous purple sandstone	5	4	510	3
White sandstone - - - -	0	6	510	9
Variegated marl with nodules-	1	9	512	6
Purple marl - - -	2	9	515	3
Purple sandy marl- - -	7	0	522	3
Purple sandstone with red spherical nodules	3	9	526	0
Purple marl - - - -	0	9	526	9
Purple sandy marl-	11	7	538	4
Shot bed, calcareous	0	0½	538	4½
Purple marl - -	11	11	550	3½
Calcareous band stained with hæmatite - -	0	1	550	4½
Purple marl with ironstone bands - -	0	7½	551	3
RED AND BLACK SHALE WITH FOSSILS—BASE OF KEELE GROUP - -	0	3	551	3
Grey marl with nodules - - -	1	4	552	7
Soft fireclay - - - -	4	6	557	1
Bass and coals - -	0	5	557	6
Indurated fireclay with traces of plants - -	3	7	561	1
Dark grey indurated marl with plants - - -	2	6	563	7
Dark indurated marl, calcareous - - - -	1	3	564	10

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Fireclay - -	1	2	566	0
Dark shale with stigmaria	1	0	567	0
Very sandy micaceous marl with plants	8	6	575	6
Fine-grained micaceous sandstone -	2	8	578	2
Fine-grained micaceous sandstone -	3	10	582	0
Dark grey indurated marl with plants	6	7	588	7
Hard grey nodular marl with ferns -	3	9	592	4
Soft grey fireclay -	2	11	595	3
Hard grey nodular marl -	3	7	598	10
Very hard coal, pyrites partings	1	0	599	10
Grey fireclay - -	1	1	600	11
Hard green sandy marl with plants	5	4	606	3
Hard green sandy nodular marl	4	10	611	1
Hard grey micaceous fine-grained sandstone -	4	10	615	11
Micaceous fine-grained grey sandstone -	0	7	616	6
Hard fine-grained green sandstone with purple mottlings -	3	9	620	3
Micaceous fine-grained purplish grey sandstone	3	9	624	0
Flaggy fine-grained micaceous purplish sandstone	4	0	628	0
Hard green and purple marl - -	6	8	634	8
Micaceous, rather coarse-grained grey sandstone	4	10	639	6
Green marl - -	1	0	640	6
Bright green marl with pellets	3	11	644	5
Soft purple marl	2	5	646	10
Green marl with pellets -	9	8	656	6
Fine-grained green sandstone	5	8	662	2
Fine-grained green marly sandstone	4	10	667	0
Fine-grained micaceous grey sandstone	5	0	672	0
Hard green sandy marl	1	9	673	9
Hard green marl with plants	1	0	674	9
Rough variegated marl -	11	1	685	10
Soft purple and ochreous marl	26	0	711	10
Indurated green sandy marl -	3	9	715	7
Dark grey shale -	2	6	718	1
Grey shale - -	6	0	724	1
Grey soapy shales, darker at bottom	4	0	728	1
COAL -	0	6	728	7
Fireclay with remains of plants - -	1	11	730	6
Fireclay with remains of plants	0	3	730	9
Grey marl with plants	2	8	733	5
Hard grey sandy shale	11	6	744	11
Compact grey shale with traces of plants	14	0	758	11
Micaceous grey sandstone with plants -	5	4	764	3
Dark grey shales with plants	7	3	771	6
COAL -	0	0½	771	6½
Fireclay -	5	2½	776	9
Fireclay	3	9	780	6
Flaggy grey sandstone with green marl partings	6	10	787	4
Highly micaceous fine-grained grey sandstone	4	9	792	1
Very fine-grained sandstone with thin dark bands -	4	10	796	11
Grey sandy shale full of plants - -	5	1	802	0
Dark grey shale with many plants - -	2	4	804	4
Dark fireclay - -	1	0	805	4

Character of Strata.	Thickness		Depth.	
	Ft.	In.	Ft.	In.
COAL - - -	0	1	805	5
Soft rotten fireclay -	1	5	806	10
Coal with pyrites faces - .	0	4	807	2
Indurated fireclay with plants	1	4	808	6
Indurated fireclay with plants	1	0	809	6
Sandy micaceous marl -	3	10	813	4
Indurated grey sandy marl	4	10	818	2
Micaceous grey flags and bands of grey shale	4	0	822	2
Very fine marl	0	10	823	0
Fine soft marl with pyrites -	5	3	828	3
Purplish-brown marl with pyrites - -	0	6	828	9
Grey shale with *Carbonia* and fish scales	0	1	828	10
Hard grey limestone (*Spirorbis*)	0	9	829	7
Highly calcareous grey marl	4	3	833	10
Calcareous purple marl -	3	2	837	0
LIMESTONE with *Ancylus* (*Carbonicola*)—BASE OF NEWCASTLE-UNDER-LYME GROUP -	0	8	837	8
Mottled marl, slightly calcareous -	1	8	239	4
Indurated grey marl with pyrites at bottom	3	6	842	10
Purple marl with shot-like concretions	17	11	860	9
Grey sandy marl	0	11	861	8
Purple marl	3	5	865	1
Grey sandy mottled marl .	4	7	869	8
Dark green grit -	2	2	871	10
Indurated fine-grained marly sandstone	2	2	874	0
Grey sandstone	0	4	874	4
Purple marl -	5	0	879	4
Purple marl with shot-like concretions -	22	0	901	4
Fine-grained green sandstone - -	15	4	916	8
Variegated purple marl- - -	130	10	1,047	6
Indurated purple marl with bands of cornstone	12	0	1,059	6
Purple marl - -	37	6	1,097	0
Black marl	5	0	1,102	0
Purple marl	48	9	1,150	9
Coarse purple grit - . -	0	7	1,151	4
Purple marl with small concretions	4	5	1,155	9
Soft purple marl	11	8	1,167	5
Purple marl -	69	10	1,237	3
Grey marl	1	5	1,238	8
Greenish grit-	2	0	1,240	8
Very coarse grit -	13	6	1,254	2
Very coarse grit	7	5	1,261	7
Hard green marl -	0	2	1,261	9
Hard purple marl	10	6	1,273	3
Fine-grained grey sandstone-	4	3	1,276	6
Indurated purple marl -	0	9	1,285	6
Purple sandy marl	26	2	1,311	8
Purple marl with gypsum veins	9	0	1,320	8
Striped purple marl -	2	6	1,323	2
Green grit with partings of green marl	6	7	1,329	9
Soft clunch - - -	1	2	1,330	11
Purple marl - - -	34	11	1,365	10
Purple clunch - - - - -	3	10	1,369	8

Character of Strata.	Thickness		Depth.	
	FT.	IN.	FT.	IN.
Purplish marl	2	4	1,372	0
Green grit with iron pyrites	3	5	1,375	5
Purple marl	74	5	1,449	10
Green sandstone	1	8	1,451	6
Purple marl	21	6	1,473	0
Green sandstone	0	6	1,473	6
Purple marl	28	6	1,502	0
Green sandy marl	4	0	1,506	0
Purple marl	0	6	1,506	6
Green sandy marl	4	0	1,510	6
Mottled purple marl	22	0	1,532	6
Indurated purple marl with sandy partings	18	8	1,551	2
Hard felspathic rock	0	6	1,551	8
Very soft purple marl	16	0	1,567	8
INDURATED GREY MARL, WITH BANDS OF FINE PURPLE GRIT TOWARDS THE BASE (BASE OF ETRURIA MARLS)	25	4	1,593	0
Indurated grey marl	7	3	1,600	3
Sandstone	0	3	1,600	6
Grey shale full of plants	7	4	1,607	10
COAL	0	10	1,608	8
Dark clunch indurated at bottom	0	9	1,609	5
Ironstone with quartz veins	0	1½	1,609	6½
Grey warrant	2	0	1,611	6½
Limestone	0	3	1,611	9½
Variegated soft marl	34	7½	1,646	5
Fireclay with plants	15	3	1,661	8
Sandstone	0	4	1,662	0
Fireclay with plants	0	6	1,662	6
Sandstone	7	9	1,670	3
Hard green marl	9	1	1,679	4
Very hard calcareous grit	1	5	1,680	9
Compact greenish grey marl	14	0	1,694	9
Indurated grey marl with veins and grit	2	6	1,697	3
No core	6	2	1,703	5
BRIGHT COAL WITH WHITE JOINTS	1	9	1,705	2
Fireclay	0	2	1,705	4
Dark shale	3	5	1,708	9
Purple marl	28	5	1,737	2
Grey marl	10	10	1,748	0
Purple marl	6	5	1,754	5
Hard dark grey marl	15	8	1,770	1
Grit with vegetable matter	0	10	1,770	11
Soft dark marl with black hard warrant	1	7	1,772	6
Grey marl with plants, sandy in places	68	9	1,841	3
COAL	0	9	1,842	0
Fireclay with plants	1	6	1,843	6
Mixed gritty marl	21	6	1,865	0
Fireclay and plants	3	0	1,868	0
Iron grit	0	3	1,868	3
Fireclay and plants	0	2	1 868	5
Ironstone	0	7	1,869	0
Fireclay	12	7	1,881	7
COAL (no core)	2	3	1,883	10

Character of Strata.	Thickness Ft.	In.	Depth. Ft.	In.
Indurated fireclay (Calcareous band at base —*Ancylus Carbonia*) -	25	8	1,909	6
Grey marl - -	15	2	1,924	8
LIMESTONE (*Spirorbis* and *Carbonia*)	0	8	1,925	4
Grey marl -	9	0	1,934	4
Grey grit with carbonaceous matter	9	0	1,943	4
Grey marl (no core)	1	6	1,944	10
Ferruginous grit -	0	6	1,945	4
IRONSTONE (BASSEY MINE) - - - -	1	0	1,946	4
COAL (no core) (BASE OF BLACKBAND SERIES)	3	6	1,949	10
Sandy marl - -	19	4	1,969	2
Indurated fireclay with fossils	0	4	1,969	6
Bass with iron - pyrites -	0	1	1,969	7
Fireclay - -	2	0	1,971	7
COAL (no core)	0	11	1,972	6
Carbonaceous shale - ,	0	1	1,972	7
Sandy fireclay with plants	3	5	1,976	0
COAL (no core) -	0	6	1,976	6
Ferruginous grit with nodules	4	6	1,981	0
Fireclay with plants -	22	0	2,003	0
COAL (no core) - -	2	3	2,005	3
Fireclay with plants	4	2	2,009	5
Very fine grey sandstone - -	3	0	2,012	5
Fireclay with plants and nodules	24	2	3,036	7
COAL (no core) -	1	3	2,037	10
Fireclay with plants	22	0	2,059	10
COAL -	4	0	2,063	10
Fireclay with plants	27	2	2,091	0
Grey fireclay with plants and bands of black shale	4	3	2,095	3
Black shale -	0	9	2,096	0
COAL - -	0	6½	2,096	6½
COAL (no core) -	2	5½	2,099	0
Fireclay- - -	1	0	2,100	0
Grey marl - - -	22	5	2,122	5
Fine-grained grey sandstone - -	19	0	2,141	5
Indurated grey marl with plants - -	6	0	2,147	5
Fireclay with plants and nodules	18	7	2,166	0
Coal Washings - -	6	0	2,172	0
Band of foul coal and fireclay -	1	5	2,173	5
COAL - -	1	10	2,175	3
Fireclay- - - -	4	10	2,180	1

SECTION No. 2.

SECTION OF STRATA AT NEW SINKING No. 2 PIT. LONGTON HALL COLLIERY.

O.D. 500 feet approx.

From Mr. G. A. Mitcheson.

Character of Strata.	Thickness.			Depth. (Plumbed).		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Clay	0	1	6			
Sandstone rock	3	0	6			
Light marl	2	2	0			
Red and mottled marl	9	2	0			
Dark grey marl	1	0	0			
COAL	0	1	11	17	1	11
Light coloured marl	10	0	0			
Sandstone rocks	1	0	0			
Metals and bass	2	0	0			
COAL	0	2	2	31	1	1
Fireclay	0	2	6			
Mottled strong marl	6	0	6			
Bastard dark stone	0	0	6			
Mottled marl	10	0	0	48	1	7
Sandstone	0	1	0			
Dark metal	1	2	0			
Coal in a slip	0	0	6			
Mottled marl	3	1	6			
Rock	0	2	0	54	2	7
Light marl with balls of stone	5	1	0			
COAL	0	0	6	60	1	1
Light marl	0	2	6			
Dark shale	1	0	0			
COAL	0	0	6			
Fireclay (good)	2	0	6			
Dark metals	1	1	0			
Stony metal	1	0	0	66	2	7
Mottled marl	1	0	6			
Red marl (good)	3	2	0			
Strong beds of rock full of bastard stone	5	1	0	77	0	1
Dark clod	0	0	6			
Red marl	0	2	6	78	0	1
Rock	2	2	0			
Red marl	0	2	0			
Strong marl with balls of rock	4	0	7			
COAL	0	0	6	85	2	2
Stone	0	0	4			
Marl (good)	3	2	6			
Metals with balls of stone	1	0	9			
Rock beds and marl	4	0	4			
Bass	0	1	6			
COAL	0	1	6	96	0	1
Fireclay	1	1	6			
Rocky marl	4	0	0			
Black shale and bass	0	2	0	102	0	7

Character of Strata.	Thickness.			Depth (Plumbed)		
	Yd.	Ft.	In	Yd.	Ft.	In.
Bastard brown stone	0	1	6			
Marl with balls of stone	1	1	0			
Mottled marl	5	1	0			
Light marl with bands of stone	1	0	3			
Limestone	0	2	0	111	0	4
Mottled marl	2	2	9			
Red marl	2	2	0			
White metal roof	2	2	0			
COAL	0	0	8			
Stone	0	2	0			
Bass	0	1	0			
BASSEY MINE STONE	0	1	8			
BASSEY MINE COAL	0	2	3	121	2	8
Fireclay	1	0	6			
Light marl	7	1	0			
LITTLE COAL	0	1	6	130	2	8
Warrant	1	1	6			
COAL	0	0	6			
Metals and bass	2	2	0			
PEACOCK COAL	0	2	10	136	0	6
Warrant	0	2	10			
COAL	0	0	6			
Marl	1	0	0			
Fireclay with rock balls	1	2	0			
Strong marl with bands of rock	7	0	0			
Black bass	1	1	0			
Grey rock	3	0	6			
Shale	6	2	0	158	0	4
CANNEL (bastard)	0	1	0			
Stone	0	0	10			
Pricking	0	0	2			
SPENCROFT COAL	1	1	0	160	0	4
Shale	1	0	10			
COAL	0	1	6			
Shale	1	0	0			
COAL	0	1	11			
Shale and bass	0	2	6			
COAL	0	0	9			
Fireclay	2	0	0			
Clunch with balls of stone	2	1	6			
GREAT ROW COAL	2	2	6	171	2	10
Fireclay	1	0	6			
Clunch	1	0	0			
Rock binds	1	1	6	175	1	10
Rock binds 4. 0. 0. and 1. 2. 0.	5	2	0			
Rock commonly called peldon	4	0	0			
IRONSTONE	0	1	0			
Black bass	1	1	6			
Light shale	3	0	0	190	0	4
Bastard stone	0	0	6			
Black bass	1	0	0			
Cannel	0	2	0			

Character of Strata.	Thickness.			Depth. (Plumbed).		
	Yd.	Ft.	In.	Yd.	Ft.	In.
CANNEL ROW COAL	1	2	0	193	1	10
Black bass	0	1	0	193	2	10
Bastard cannel	0	0	8			
COAL -	0	0	10	194	1	4
White metal with bands of bastard stone	0	1	6			
Fireclay -	4	0	0			
Soft shale-	2	0	0			
Rock binds -	7	2	0			
Metal with bats of stone	3	0	0			
COAL -	0	0	2	211	2	0
Soft shale-	1	1	6			
Light metal -	3	1	6			
Metal with rock bands	1	1	6			
Light metal	0	2	6	219	0	0
Black bass	1	1	0			
IRONSTONE -	0	0	4			
Black bass -	0	1	0			
Ironstone -	0	0	3			
Black bass	1	0	6			
CANNEL	0	0	9			
COAL -	0	2	0	222	2	10
Black bass	0	1	0			
COAL -	0	2	2	224	0	0
Grey metals -	1	0	6			
IRONSTONE (bastard)	0	0	3			
Hard grey rock -	1	0	7			
Black bass	0	2	5	227	0	9
Stone	0	0	6			
Clod and bass	0	2	6			
DEEP MINE IRONSTONE	0	0	6			
Bass-	0	2	6			
DEEP MINE COAL (*Fault, downthrow South* 2ft. 9in)	1	0	0	230	0	9
Light metal full of balls of bastard stone -	5	0	0			
Light metal full of balls of bastard stone	5	0	0			
Rock (very hard)	0	1	6			
Black bass	1	0	0			
Rock binds -	0	1	6			
Light marl-	1	2	6			
IRONSTONE -	0	0	5			
Black Bass	0	2	0			
Ironstone -	0	0	2			
Black bass-	0	1	6			
IRONSTONE -	0	0	2			
Light metal -	1	1	0			
Black bass	0	1	6			
Stone	0	0	2			
Bass-	0	1	2			
Stone -	0	0	5			
CHALKY MINE COAL -	0	0	10	248	0	7
Strong fireclay (rocky)	2	1	3			
Ironstone -	0	0	5			
COAL -	0	1	2	251	0	5
Fireclay -	1	0	0			

Character of Strata.	Thickness.			Depth. (Plumbed).		
	Yd.	Ft.	In.	Yd.	Ft.	In.
COAL	0	1	2			
Bastard ironstone	1	0	0			
Rock binds	2	2	4			
TOP COAL	0	0	6	256	2	4
Clod	0	0	2			
BOTTOM COAL	0	0	7			
Fireclay	0	2	0			
Black bass	1	0	0			
Rock binds	1	1	0			
Hard rock	1	1	0			
Hard stone	0	0	4			
Bastard ironstone	0	0	6			
Bass	1	0	0			
IRONSTONE (good)	0	0	4			
Bass	1	0	6			
IRONSTONE (good)	0	0	2			
Bass	0	2	0			
IRONSTONE	0	0	4			
Bass	1	0	0			
Clod	0	0	10			
Bastard stone	0	0	3			
COAL (with water)	0	1	8	266	1	1
Strong fireclay	1	1	6			
Black bass	3	0	0			
COAL	0	0	6	271	0	1
Fireclay with balls of stone	1	0	6			
Rocky marl	3	0	0			
Soft marl	0	2	0			
Metal with bands of rock	3	0	0			
Bass	0	2	9			
IRONSTONE	0	0	3			
Bass	0	2	8			
IRONSTONE	0	0	4			
Black bass	0	1	0			
IRONSTONE	0	0	10			
Black bass	0	0	6			
COAL	0	0	6	281	2	5
Strong metal with hard bands	2	0	0			
Rock (light coloured)	0	1	4			
Marl with strong rock bands	2	0	0			
Fireclay	0	1	8			
COAL	0	0	4	286	2	9
Fireclay with rock	3	0	0			
Metal (light)	0	2	0			
COAL	0	0	4	290	2	1
Slums	1	0	6			
COAL	0	0	4	291	2	11
Bass and dirt	1	2	6			
COAL	0	0	4	293	2	10
Fireclay	1	2	0			
Black bass	0	1	6	296	0	3
IRONSTONE	0	0	4			
Bass	0	0	6			

Character of Strata.	yd.	ft.	in.	Thickness. Yd.	Ft.	In.	Depth (Plumbed). Yd.	Ft.	In.
Stone				0	0	6			
Bass				0	1	6			
IRONSTONE				0	1	6			
Metal with rock beds				3	0	0			
Strong rock				10	0	0			
Rock binds				2	0	0			
Bass				3	1	0			
Metal with bands of stone				1	2	0			
COAL				0	2	0	328	0	7
Fireclay				1	1	0			
Rock, light				2	0	0			
Black shale				0	1	6			
Rock binds				4	1	0			
Strong grey rock				10	2	0			
KNOWLES COAL — Top coal	0	1	6						
Black bass	0	1	6						
Middle coal	1	2	6						
Dirt	0	0	6						
Coal	0	0	6	3	0	6	340	0	7
Fireclay				2	0	0			
Rock binds				2	0	0			
Bastard stone				0	0	6			
COAL				0	0	6	344	1	7
Black Bass (bands of ironstone)				7	2	0			
Black bass (bands of ironstone)				5	0	0			
Brown stone (bastard stone)				0	0	6			
Fireclay and bass				1	1	6			
Hard rock				13	2	0			
Hard metal				1	0	6			
Black bass				1	1	6			
IRONSTONE				0	0	3			
Bass				1	0	6			
Bastard stone				0	0	6			
Bass				1	0	6			
IRONSTONE				0	0	3			
Bass				1	1	0			
Stone				0	0	6			
Bass				1	2	0			
Stone				0	0	10			
Bass and Stone				1	2	0			
IRONSTONE				0	0	4			
Bass				1	1	0			
Stone				0	0	4			
Bass				0	2	0			
IRONSTONE				0	0	2			
Bass				1	0	3			
IRONSTONE				0	0	2			
Bass				1	0	0			
CANNEL				0	1	6			
Bass				2	0	6			
COAL				0	0	9	389	1	11
Bass				0	0	9			

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth (Plumbed). Yd	Ft.	In.
COAL - - -	0	2	0	390	1	8
Black bass with stone - - -	2	0	0			
Bastard stone - - - - -	0	0	7			
COAL - - - - - - -	0	1	3	393	0	6
Fireclay - -	1	1	6			
Metal with bands of stone - - - -	2	1	8			
Rock and rock binds - -	6	1	3			
Rock and rock binds - - -	4	0	3			
CANNEL - - -	0	0	4			
Stone - -	0	0	8			
COAL - - - - - - - -	0	1	8	408	1	4
Black shale - - - -	1	0	4			
Fireclay - - - - - -	0	1	6			
Strong rock - - -	6	0	0			
Rock (peldon) - - - - - - -	1	0	0			
Rock binds - - - - - -	5	0	0			
Blue metal and rock binds- - - -	5	0	0			
Black bass - - - - - - -	1	0	6			
Rock binds and stone - - -	1	0	6			
Dark clunch with mussel beds - -	2	0	0			
Black bass - - -	0	1	6	432	0	2
COAL - - - - -	0	2	11	433	0	1
Grey metal with bands of ironstone - - -	7	2	0			
Black bass - - -	0	2	0			
ASH COAL - - -	2	0	6	443	1	7
Bat - -	0	2	0			
Marl and coal - - - -	4	1	6			
Rock and rock binds and balls of stone -	2	2	0			
LITTLE COAL - - - - - -	0	1	8	451	2	9
Fireclay - - - -	1	1	6			
Metal with balls of stone - -	3	0	0			
Rock binds with beds of metal - - - -	5	2	0			
Hard rock - - - -	5	1	6			
Mixed ground -	2	1	0			
Black bass with nodules (small) of stone -	3	2	6			
Black bass - - -	1	0	0			
Shale-like fireclay - -	2	1	0			
Black bass with three beds of stone varying from 1″ to 3″ -	1	0	6			
LITTLE MINE COAL -	0	2	9	479	0	6
Fireclay - - -	1	2	0			
Black bass and clunch - - - -	5	0	0			
Rock - - - - - -	1	1	9			
Strong light metals - - -	1	2	0			
Bed of coal and smut - -	2	0	6			
Black bass - - - -	2	0	0			
Soft ground mixed with coal - -	0	2	0			
Light metal with bands of rock - - -	3	0	0			
Rock - - - - - - -	1	1	9			
Bass with beds of coal 6″ thick - - -	2	0	0			
GIN MINE COAL - - - - - - -	1	0	1	493	0	0
Fireclay with bands of stone - - - -	1	2	0			
Rock and rock bands (strong) - - - -	3	1	0			

Character of Strata.	Thickness.			Depth. (Plumbed.)		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Blue strong metals with bands of rock	4	0	0			
Binds	1	0	0			
Blue clunch, slaty	5	0	0			
Bed of stone	0	0	4			
Black bass	3	1	0			
Bed of stone	0	0	2			
Strong clunch	3	0	0			
Black bass	3	0	0			
COAL *with bands of stone varying from 4″ to 15″*	0	0	4	518	1	11
Black bat	0	2	0			
Rock and rock binds to dark floor	9	0	11			
Rock and rock binds	2	1	2			
Rock and metals	3	0	0	534	0	0
Black bass	0	0	6			
Black bass	10	0	0			
Black bass with bands of stone	8	0	0			
COAL	0	0	4	552	0	11
Rock	5	0	8			
Rock	8	2	0			
Soft shale	1	1	0			
Band of stone	0	0	6			
Rock	11	0	0			
Bass and black shale	11	2	0			
DOCTORS MINE COAL	0	1	7	590	2	4
Black batt	0	1	0			
Fireclay	1	1	0			
Bass with bands of coal	1	0	0			
Fireclay with balls of stone	5	1	10			
Soft pricking	1	0	0			
Rock binds and fireclay	6	1	0			
Rock	1	1	0			
Clunch	1	1	0			
Rock	2	2	10			
Black bass. (A band of marine-fossils runs through this bass mixed with scales of fossil fishes.)	5	1	6			
Fireclay and strong metals	1	2	0	619	0	9
Black bass (full of fossil shells)	0	2	0			
Bastard ironstone	0	0	6			
Soft pricking	0	0	2			
COAL	0	1	2	620	2	7
Soft firelacy bands of stone	1	1	1			
Rock	9	0	0			
Bass	5	0	0			
Rock	2	2	6			
Metals	2	0	0			
Bass, black and grey	11	0	0			
Cannel	0	1	2			
MOSS COAL { COAL	0	0	6			
MOSS COAL { Dirt	0	0	6			
MOSS COAL { COAL	1	1	3			
Mixed ground	7	1	7			
COAL	1	1	0			
Bass metals, etc., with bands of stone	3	1	0	685	0	0

SECTION No. 3.

GOLDEN HILL COLLIERY, LONGTON.

O.D. 553·9 Feet.

From M.S. in Survey Office.

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Clay	2	1	0			
Bass	0	2	0			
IRONSTONE	0	0	2½			
Bass	0	2	0			
IRONSTONE	0	0	2½			
Bass	0	2	0			
IRONSTONE	0	0	2½			
Bass	0	2	0			
IRONSTONE	0	0	2½			
Bass	1	0	0			
COAL	0	0	3			
Marl or fireclay	11	0	0			
IRONSTONE	0	0	4			
COAL	0	1	0	17	2	4
Marl or fireclay	1	0	8			
IRONSTONE	0	0	10			
COAL	0	1	0			
Marl or fireclay	8	1	1			
Rock	10	2	6			
Grey metal	2	1	6			
Rock	0	1	0			
Grey marl	1	0	0			
Rock	1	1	6			
Grey metal	0	1	7			
Rock	2	1	6			
Grey metal	2	1	0			
Strong rock	5	1	9			
Grey metal	6	0	0			
Black bass	6	0	0			
RIDER COAL	1	0	11			
Dark metal	1	2	6			
ASH COAL	2	1	0			
Fireclay or marl	4	1	0			
Rock	9	0	0			
Grey metal	2	1	8	85	2	8
Ironstone band	0	0	3			
Grey metal	6	1	9			
Brown and black metal	5	2	0			
LITTLE MINE COAL	0	2	6			
Metal mixed with rock	14	0	0			
Black metal	7	0	0			
GIN MINE COAL	0	1	6			
Strong dark metal with rock	25	2	6			
Bass	5	1	6			
COAL	0	0	6	—		
Dark metal	2	1	6	157	0	4

SECTION No. 4.

SECTION OF LAURA PIT, CHATTERLEY AND WHITFIELD COLLIERY.

From Mr. E. B. Wain.

Character of Strata.	Thickness. Yd.	Ft.	In.
Filled up dirt -	1	0	0
Yellow clay - -	2	1	0
Soft rock - -	2	0	0
Rock - - - - - -	12	0	0
Rock binds - - - - - -	6	1	0
Strong metal - - - -	7	2	6
Bass - - - -	0	0	6
TEN FEET COAL -	2	1	0
Warrant - -	2	0	0
Strong stone binds - - - - -	7	2	0
Strong blue binds - - - -	11	0	0
Rock - - - - -	3	0	0
Ironstone binds - - - - - - - -	8	0	0
Blue bass with ironstone nodules - -	0	1	6
BOWLING ALLEY COAL - - - - - - -	1	0	0
Fireclay - - - - - - - - - -	1	1	0
Rock binds - - - - - - -	6	2	0
Rock - - - - - - -	17	0	0
HOLLYLANE COAL - - - - - - -	1	0	2
Fireclay - - - - - - -	0	0	8
Warrant - - - - - -	1	2	6
COAL - - - - - -	0	1	2
Grey metal - - - - - - -	11	1	6
Rock - - - - - -	1	2	0
Blue metal - - - - - - - -	3	1	0
Shale with ironstone binds - - - - - - - -	1	1	0
Strong grey metal - - - - - -	1	1	0
Grey rock - - - - - - - -	4	2	0
Dark rock - - - - - - - - - -	1	0	0
Grey rock - - - - - - - -	1	0	8
Brown rock - - - - - - - -	1	2	6
Soft metal - - - - - - - - - -	5	0	3
HARD MINE COAL - - - - - - -	1	1	0
Rock metal - - - - - - - -	3	0	0
Dark shale - - - - - -	0	2	0
Soft fireclay and ironstone nodules - - -	6	1	0
Grey metal - - - - - - - - -	23	2	6
Grey hard rock - - - - - - -	39	0	0
Blackshale and ironstone nodules - - -	27	0	0
IRONSTONE MINE COAL - - - - - - -	0	2	1
Strong marl ironstone nodules - - - - - -	5	2	6
COAL - - - - - - - - - - -	0	0	6
Grey rock binds - - - - - - - -	10	2	0
SEVEN FEET ROCK - - - - - - - - -	7	2	6
Granite rock - - - - - - - - -	4	0	0
Rock - - - - - - - - - - - - -	6	0	0
Strong grey rock binds - - - - - -	3	2	0
Strong grey rock binds - - - - - -	7	2	7
Grey rock - - - - - - - - - -	2	0	0
Black metal - - - - - - - -	2	0	7

Character of Strata.	Depth.		
	Yd.	Ft.	In.
BAMBURY COAL, Tops	1	0	6
Dark shale	0	0	6
BAMBURY COAL, Bottoms	0	2	10
Grey marl	1	0	0
Grey rock	5	0	0
Black, strong metal	12	2	6
Strong metal	33	2	7
Grey rock	1	2	0
Strong metal	8	2	0
COCKSHEAD COAL	2	1	5
Black smut	0	0	3
Strong black bass	5	0	0

SECTION No. 5.

NEW UBBERLEY COLLIERY.

O.D. 465. 4 Feet.

From Mr. E. B. Wain.

Character of Strata.	Thickness.		
	Yd.	Ft.	In.
Old bank	4	0	0
Clay	1	2	0
Clay, gravel and sand	7	0	4
Brown marl	1	1	0
Grey marl	4	0	0
Rock	0	1	0
Metal	0	1	3
Rock	0	1	0
Metal	2	0	5
Bass	1	0	6
YARD COAL	0	2	0
Metal	7	2	6
RAGMAN COAL	1	0	0
Faulty metals	12	0	6
Faulty metals with ironstone nodules	3	2	0
Rock	7	0	0
Metals	1	2	0
BIRCHES COAL	1	1	6
Holing clod	0	0	6
Fireclay	3	1	0
Faulty metals	17	1	0
Three bands of bass	1	1	8
Metal	1	0	0
Rock	0	1	0
Metal	1	1	0
Rock	0	2	0
Faulty metal	2	2	0
Dark shale	0	1	4

Character of Strata.	Thickness.		
	Yd.	Ft.	In.
COAL	0	1	0
Rock binds and faulty metals	5	1	0
Faulty metals	7	0	0
Fireclay	1	1	0
Strong metals	12	2	0
Soapy metals	2	2	0
Bass	1	0	3
BELLRINGER COAL	0	1	6
Blackrock	1	1	6
COAL	0	0	9
Metal	1	0	5
Grey rocks	9	1	0
Strong metals	0	1	6
Grey rocks	3	0	0
Soapy metals	1	1	6
Strong metals	8	2	0
Rock binds	4	2	0
TEN FEET ROCK	13	1	0
Metal	2	2	0
Faulty bass	4	1	6
Metal	0	2	6
TEN FEET COAL	2	1	0
Holing clod	0	1	0
COAL	0	1	0
Faulty marl	3	1	0
COAL	0	2	0
Marl	1	1	0
Rock binds	13	1	6
Bass	1	2	0
Metal	8	1	0
Faulty rock and rock binds	4	0	0
Metal	3	1	6
Bass	0	1	7
BOWLING ALLEY COAL	1	1	6
Fireclay	1	0	0
Rock	0	2	6
Faulty metals	8	2	9
Faulty bass	1	1	0
Fireclay	0	2	7
Rock and faulty binds	5	1	0
Strong metals	12	2	8
Bass	0	0	4
HOLLY LANE COAL	1	1	2
Clod	0	1	0
COAL	0	2	0
Faulty fireclay	4	1	0
Faulty binds and rock	2	0	0
Soapy metals	7	2	6
Black bass	0	2	10
Soapy metal with bass balls	8	1	0
Bass	0	0	6
HARD MINE COAL	1	2	6
Fireclay	1	0	0

Character of Strata.	Depth.		
	Yd.	Ft.	In.
Black shale	0	2	0
Faulty fireclay and balls	5	2	4
Faulty metals mixed with rock	4	1	6
Faulty metals	4	2	10
Faulty metals mixed with coal	8	0	0
Faulty metals mixed with bass and coal	22	2	8
COAL	0	0	4
Faulty metals	8	1	0
Bass	1	1	0
LITTLE MINE COAL	0	2	0
Fireclay with rock	1	0	7
Faulty metals	13	1	0
Bambury rock	17	2	0
BAMBURY COAL	0	0	6
Dark metal	3	0	4
Faulty marl and fireclay	7	0	6
Faulty marl, fireclay and rock binds	4	0	0
Faulty metals	13	0	0
Shale	2	0	0
Rock and rock binds	6	2	6
Grey metals	5	0	0
Black bass	3	0	0
Cannel	0	1	0
Shale	1	1	4
Dark fireclay	0	2	8
Shale and bass	4	0	0
Bass and stone	0	1	4
COCKSHEAD COAL	2	2	0
Holing clod	0	0	9
Hard brown clump	0	1	9
Faulty warrant	3	0	8
Faulty rock and binds	6	0	0
Faulty metals	2	0	0

SECTION NO. 6.

NO. 2 SHAFT, FLORENCE COLLIERY, LONGTON.

O.D. 520 Feet (approx.).

From Mr. G. A. Mitcheson.

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In
MOSS COAL	1	2	6	733	1	0
Grey metal	5	0	9			
LITTLE COAL	0	2	0			
Grey metals	4	2	6			
Smut band	0	1	6			
Grey metal with rock binds	14	0	6			
Rock binds	0	1	0			
Grey metals	1	1	4			
Rock binds	0	1	10			

Character of Strata.	Thickness. Yd. Ft. In.	Depth Yd. Ft. In.
Grey metals	5 0 8	
Rock	2 0 0	
Shaly rock binds	2 0 3	
YARD ROCK	9 0 3	
Shaly rock binds	0 0 6	
YARD ROCK	5 1 0	
Dark parting	0 0 2	
Yard rock with quartz veins and balls of stone	4 2 10	
Rock bands with balls of stone	0 1 6	
YARD ROCK	9 1 0	
Dark coaly parting	0 0 0¼	
Rock with calamites	0 2 1¾	
Rock binds	0 0 7	
Sandstone rock full of coaly matter and plants	2 1 6	
Conglomerate	0 0 9	
Grey metal full of slips	8 1 9	
Grey and black bass	4 1 3	
YARD COAL { Tops 2 8		
Pricking 0 4		
Bottoms 4 10 }	2 1 10	
Soft metals	1 1 0	
HAMS COAL	1 1 0	
Hard grey clunch	8 0 2	
COAL	0 1 0	
Dirt	0 1 3	
COAL	1 0 5	
Clunch with balls of stone	1 1 0	
Rock binds	2 1 9	
Hard grey metal	2 2 0	
Dirt	0 0 9	
COAL	0 1 0	
Dirt	0 0 11	
COAL	0 1 7	
Soft dirt full of plant remains	1 0 9	
Rock	4 0 11	
Rock bind parting	0 0 8	
Rock	2 2 9	
Binds	1 0 8	
Metals	5 0 8	
COAL	0 1 7	
Clunch	2 1 11	
Metals with thin hard bands of stone	25 0 6	
COAL	0 2 3	
Rock with bind partings	5 2 3	

SECTION No. 7.

FLORENCE COLLIERY, LONGTON.

No. 1 Shaft.

O.D. 520 Feet (approx.).

From Mr. G. A. Mitcheson.

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
Embankment -	6	0	0			
Clay - - - -	5	2	0			
Red, grey, and mingled marl - -	18	1	6			
Black ring -	0	0	3			
Red, grey, and mingled marl -	9	0	0			
Rock and rock-binds- -	4	1	0			
Red and grey marl -	8	2	6			
Rock, rock binds, and marl -	10	2	11			
Red and white rock -	7	1	0			
Red marl - - - -	15	0	0			
Rock - -	1	1	6			
Red and mottled marl	27	2	7			
Marl and rock binds - - -	7	0	8			
Purple marl - - -	2	2	0			
Rock, mixed marls with ironstone nodules -	12	2	0			
Blue, purple, and white rock -	10	0	4			
Clod, marl, bat, etc. - - - - -	8	2	6			
Black bat - - - - - -	0	0	8			
Clod, marl, and binds - -	11	1	8			
Green rock - - - -	5	1	5			
Mingled ground - - - -	14	2	0			
Green rock - - - -	8	2	0			
Black bat -	0	0	6			
Fireclay and grey rock - - -	5	2	6			
Ironstone - - -	0	0	8			
GREEN ROCK (? BASE OF ETRURIA MARLS) - -	5	0	0	208	1	2
Bat and grey marl - - - -	2	0	0			
Mingled ground - - - -	5	2	5			
Fireclay - - -	1	2	6			
Rock-binds - - - - -	4	0	0			
Fireclay - - - - - -	1	0	0			
COAL AND FIRECLAY - - - - -	3	0	5			
COAL - - - - - -	0	2	0			
Fireclay - - - - - -	1	2	4			
Grey marl - - - -	2	1	2			
Mingled ground - - - -	4	2	2			
Dark fireclay -	0	1	11			
Mingled ground - -	2	0	3			
Green rock-binds -	0	1	4			
Mingled ground - -	8	0	0			
Blue clod - - - - - - -	0	1	4			
Mingled ground - - - -	9	1	6			
Light rock - - - -	2	0	10			
Mingled ground - -	1	0	5			
Light clod - -	0	2	4			
Mingled ground -	5	2	6			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
COAL - - - - - - -	0	0	6			
Fireclay - - -	0	1	8			
Mingled ground - -	2	0	10			
Rock-binds -	2	0	11			
Fireclay clod and fireclay	0	2	9			
COAL - -	1	2	3			
Fireclay and ironstone measures	6	1	10			
Rock binds	0	1	7			
LIMESTONE (*Spirorbis, Entomostraca*)	9	2	10			
Mingled marl clod and fireclay -	0	2	2			
BASSEY MINE IRONSTONE AND COAL	0	1	11	299	0	10
Light marl	9	2	9			
Clod and parting -	0	1	7			
Marl ironstone and fireclay -	3	2	2			
COAL - - -	0	0	10	313	2	2
Fireclay - - - - - -	3	0	7			
COAL - - - - - - - - -	0	2	3			
Fireclay, rock, and ironstone - - -	4	2	10			
Fault of 60 *yards.*						
COAL - - - - - - - -	0	2	9			
Fireclay - -	0	1	5			
COAL - - - - -	0	1	7	327	2	7
Coal, fireclay, rock, etc. - - - -	6	1	0			
Ironstone measures - - -	2	2	3			
DEEP MINE COAL - - -	0	2	9	334	1	7
Rock binds - - - - -	8	2	4			
Bat - - - - - - -	0	2	0			
Rock binds - - - - - - -	3	0	5			
CHALKEY MINE IRONSTONE - - - - - -	3	1	2			
Fireclay, bass, clunch, etc. - - - -	9	1	9			
NEW MINE IRONSTONE - - -	3	0	11			
NEW MINE COAL - - - - -	0	1	6	363	2	8
Fireclay slums, and rock-binds - - -	5	1	11			
COAL - - - - - - -	0	1	5	370	0	0
Slums, rock, fireclay - - - -	4	0	3			
HANBURY MINE IRONSTONE - - -	2	1	8			
Fireclay and rock binds - - - -	3	0	7			
HANBURY COAL - - - - - - - -	0	0	8			
Fireclay - - - - - - - -	4	0	7	386	0	2
Fireclay and slums - - - - -	7	0	8			
RAGMINE IRONSTONE - - -	1	2	1			
Rock binds and rock - - -	19	2	0			
Ironstone measures - - - - - - -	4	1	11			
COAL - - - - - - - - - - -	0	2	5	418	0	10
Rock binds - - - - - - - -	4	2	1			
COAL - - - - - - - - - - -	0	1	7	423	2	6
Bass and fireclay - - - - - -	1	1	11			
KNOWLES COAL - - - - - - - -	2	0	1	427	0	0
Clunch - - - - - - -	2	1	4			
Ironstone measures - - - - -	1	2	10			
Fireclay and rock binds - - - - - -	2	2	3			
Ironstone measures - - - - - -	1	2	4			
Bass with ironstone - - - -	4	0	7			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Fireclay and rock binds	17	2	8			
KNOWLES IRONSTONE	8	0	6			
Coal and bass	0	2	3			
Fireclay and slums	5	0	3			
Coal and clod	0	1	2			
BLACK MINE IRONSTONE	1	2	8			
COAL	0	1	10	475	0	2
Fireclay and slums	2	2	5			
Rock binds and rock	12	1	4			
Bass	3	0	7			
RIDER COAL	0	1	8	494	0	2
Fireclay, rock binds, etc.	14	2	0			
ASH COAL	2	0	3	510	2	5
Fireclay, rock-binds, etc.	21	0	1			
COAL	0	0	6			
Rock binds	9	0	0			
Bass, ironstone, etc.	4	1	8			
LITTLE MINE COAL	1	2	0	547	0	8
Bat, rock, and binds	7	1	11			
COAL	0	0	8			
Binds and clunch	8	0	9			
GIN MINE COAL	0	2	4	564	0	4
Bat and rock	5	0	6			
Rock binds	12	1	10			
Bass	4	1	5			
COAL	0	0	10			
Warrant	3	1	8			
Rock binds	11	1	5			
Binds and ironstone	0	1	10			
Rock binds	13	0	0			
Bass	3	1	2			
Fireclay and bass	9	0	10			
Ironstone	0	0	7			
Bass, rock, etc.	16	2	7			
DOCTORS MINE COAL	0	1	5	645	1	5
Fireclay and binds	9	1	5			
Rock	21	3	2			
Black and grey bass	8	1	2			
COAL	0	0	5			
Binds, fireclay, bass	7	0	2			
Ironstone	0	0	3			
Bass with ironstone	5	1	7			
Fireclay, clod, slums, and coal	1	2	4			
Fireclay	3	0	4			
Coal and slum	0	0	11			
Fireclay	3	0	4			
Binds	2	2	10			
Bass	0	1	6			
Binds	8	0	3			
Bass	0	2	3			
Soapy metals	6	0	8			
MOSS COAL	1	2	6	726	1	7
Clunch	7	1	1½			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Coal and bass	0	2	6½			
Clunch	18	2	10			
Strong rock binds	9	1	1			
Shale, clunch, and rock	1	0	10			
Rock and clunch	2	2	8			
"YARD COAL" ROCK	10	2	9			
"YARD COAL" ROCK	18	2	3			
Grey binds	11	1	1	—		
Dark grey bass	2	2	1	—		
Black bass	1	2	6	—		
YARD COAL	2	1	10	815	1	2
Soft metals	1	0	11			
HAMS COAL	1	1	0	818	0	1
Clunch	8	0	2			
COAL	0	1	3			
Dirt and coal	0	2	3			
COAL	1	0	2	828	0	11
Binds	4	2	2			
Dirt and coal	1	2	10			
Grey metal	1	1	0			
Rock	6	2	0			
Rock binds	2	0	8			
Metals	3	2	11			
COAL	1	1	11	850	2	5
Grey metals	0	1	0			
Rock	1	1	9			
Metals	3	2	2			
Metals	1	1	0			
Hard band	0	0	4			
Metal	0	2	0			
Hard band	0	0	9			
Grey metal	5	0	10			
Soft metal	0	0	6			
Grey metal	2	2	2	866	2	11

SECTION No. 8.

No. 8 PIT, ADDERLEY GREEN COLLIERY.

O.D. 626 Feet (approx.).

From Mr. R. J. Haines.

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Soil	0	0	11	0	0	11
Clay	1	0	4	1	1	3
Red rock	1	0	9	2	2	0
Yellow rock	1	2	4	4	1	4
Red rock	1	0	8	5	2	0
Yellow rock	1	0	3	6	2	3
Mixed ground	1	0	0	7	2	3
Red rock	3	1	0	11	0	3
Yellow rock	1	1	6	12	1	9

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Red rock	1	1	3	14	0	0
Grey rock	2	0	1	16	0	0
Yellow rock	8	0	0	24	0	0
Red rock	5	0	0	29	0	0
YARD COAL and very inferior bass	1	0	0	30	0	0
Blue metals	9	0	0	39	0	0
BIRCHES ROCK	13	0	0	52	0	0
Grey rock binds	15	0	0	67	0	0
Blue metals	5	0	0	72	0	0
BIRCHES COAL	1	0	0	73	0	0
Grey warrant and stone	5	0	0	78	0	0
Blue metals	4	0	0	82	0	0
Strong black bass	2	0	0	84	0	0
Strong grey rock	6	0	0	90	0	0
Strong blue metals	4	0	0	94	0	0
Black bass and *coal*	0	1	0	94	1	0
Strong grey rock binds	9	2	0	104	0	0
Strong stony metals	6	0	0	110	0	0
Strong rock	4	0	0	114	0	0
Metals	8	0	0	122	0	0
Stone	0	1	0	122	1	0
COAL	0	2	0	123	0	0
Bass	4	0	1	127	0	1
Mixed strong black ground	8	0	0	135	0	1
Rock binds mixed	16	1	0	151	1	1
Grey metals	2	0	0	153	1	1
Black bass	7	0	0	160	1	1
TEN FEET COAL	1	0	4	161	1	5
Parting	0	2	0	162	0	5
MIDDLE COAL	0	1	8	162	2	1
Parting	2	0	0	164	2	1
BOTTOM COAL	0	2	0	165	1	1
Rock	5	0	5	170	1	6
Metal, fireclay, and bass	12	1	0	182	2	7
Metal with balls of stone	7	0	6	190	0	1
Rock, binds, metal, clod, bass	5	2	3	195	2	4
BOWLING ALLEY COAL	1	1	2	197	0	6
Rock and fireclay	3	2	7	201	0	1
Metal bass and rock	9	1	10	210	1	11
Binds metal and bass	11	0	10	221	2	9
HOLLY LANE COAL	1	0	2	222	2	11
Fireclay	0	0	6	223	0	5
Bottom	0	2	8	224	0	1
Warrant and metal with stone	6	1	3	230	1	4
Bass, binds, and metal	16	1	0	246	2	4
HARD MINE COAL	1	1	2	248	0	6
Fireclay	0	2	5	248	2	11
BILLY COAL	0	2	10	249	2	9
Pricking and metal with stone	9	2	10	259	2	7
Binds and metals	1	1	5	261	1	0
NEW MINE or STINKERS COAL	1	2	0	263	0	0
Fireclay with stone and rock	6	1	11	269	0	11
Metal and rock	10	0	10	279	2	9

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Blue metal, stone, and rock	5	1	1	285	0	10
Black shale and metal	14	2	6	300	0	4
Bass clod and bass with stone	4	2	0	304	2	4
COAL	0	0	3	304	2	7
Stone metal and rock	5	2	0	310	1	7
Pricking bass and metal	4	1	0	314	2	7
LITTLE MINE COAL	0	2	5	315	2	0
Pricking metal and fireclay	12	0	11	327	2	11
Rock and metal	7	1	0	335	0	11
Fireclay warrant and metal	13	0	3	348	1	2
Rock and metal	9	0	4	357	1	6
BAMBURY COAL	1	1	2	358	2	8
Pricking. metal, coal, and bass	9	2	9	368	2	5
Metal rock and stone	18	1	11	387	1	4
Bass and metal	4	0	2	391	1	6
Rock binds and metal	12	1	0	403	2	6
Bass and pricking with ironstone bands	2	1	1	406	0	7
COCKSHEAD COAL	2	2	6	409	0	1
Warrant metal and bass	3	1	4	412	1	5
Rock metal, bass, and stone	13	0	1	425	1	6
Bass with shale and metal	5	0	1	430	1	7
Metal and hard rock	6	1	11	437	0	6

SECTION No. 9.

MOSSFIELD COLLIERY, LONGTON.

O.D. 600 Feet.

From Mr. F. Rigby.

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In
New made ground	7	10	7	10
Brick clay	9	0	16	10
Shaley rock	19	2	36	0
Rock binds	38	0	74	0
Rock	13	6	87	6
Blue metal	7	2	94	8
Bass	1	2	95	10
Blue metal	1	4½	97	2½
Bass	6	8	103	10½
YARD COAL	4	0	107	10½
Fireclay	25	2	133	0½
COAL	1	8	134	8½
Fireclay	9	6	144	2½
Rock	46	7½	190	10
Metal	10	4	201	2
BIRCHES COAL	4	6	205	8
Fireclay	8	1	213	9
Blue metal	19	3	233	0
Bass	5	9	238	9
Fireclay	0	4	239	1
Bass	1	4	240	5

Character of Strata.	Thickness. Ft.	In.	Depth. Ft.	In.
Rock binds	27	4	267	9
Bass	1	0	268	9
COAL	0	8	269	5
Rock	3	3	272	8
Fireclay	3	3	275	11
Rock binds	13	9	294	8
Bass with stone	1	6	296	2
Gristy rock	5	6	301	8
Strong fireclay	32	5	334	1
Fireclay	6	7	340	8
Bass	5	7	346	3
COAL	0	6	346	9
Soft Fireclay	5	0	351	9
Rock binds	9	0	360	9
Fireclay	3	6	364	3
Metal with balls of stone	14	10	379	1
Fireclay with balls of stone	26	10	405	11
Strong fireclay	8	0	413	11
Strong fireclay	21	9	435	8
Binds	24	7	460	3
Grey metal	4	7	464	10
Brown stone	0	3	465	1
Fireclay	0	6	465	7
Bass	12	7	478	2
Fireclay	1	9	479	11
Bass	1	4	481	3
COAL	1	0	482	3
Bass	1	0	483	3
TEN FEET COAL	4	6	487	9
Marl	5	3½	494	0½
COAL	1	9	494	9½
Fireclay	2	3	497	0½
Soft fireclay	4	0	501	0½
COAL	2	5	503	5½
Fireclay	1	1	504	6½
Rock	15	5½	520	0
Metal	21	6	541	6
Pricking	0	3	541	9
Bass	3	11	545	8
Strong binds	10	10	556	6
Stone	0	7	557	1
Metal with balls of stone	10	7	567	8
Black smut	0	3	567	11
Metals with ironstone	11	8	579	7
Strong rock	1	3	580	10
Binds	1	0	581	10
Metal with stone	4	7	586	5
Metal	8	0	594	5
Clod	1	8	596	1
Bass	0	9	596	10
BOWLING ALLEY COAL	4	10	601	8
Rock	1	5	603	1
Fireclay	6	8	609	9

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Rock	2	9	612	6
Pricking	0	9	613	3
Metal	7	7	620	10
Bass	7	0	627	10
Metal	11	6	639	4
Rock	2	9	642	1
Binds	19	10	661	11
Metal	13	9	675	8
Bass	0	3	675	11
HOLLY LANE COAL	4	9	680	8
Pricking	0	9	681	5
COAL	2	3	683	8
Warrant	6	9	690	5
Metal with stone	12	6	702	11
Bass	1	2	704	1
Binds	10	9	714	10
Metal	17	9	732	7
Bass	5	6	738	1
Metal	13	5	751	6
Bass	0	5	751	11
HARD MINE COAL	4	11	756	10
Fireclay	2	5	759	3
BILLY COAL	2	10	762	1
Pricking	0	4	762	5
Metal	2	6	764	11
Metal with stone	27	0	791	11
Binds	2	8	794	7
Metal	1	9	796	4
STINKERS COAL	5	6	801	10
Fireclay	5	7	807	5
Strong fireclay with stones	13	5	820	10
Rock	0	5	821	3
Soft metal	2	1	823	4
Rock	28	10	852	2
Blue metal and stone	2	2	854	4
Rock	1	8	856	0
Metal	12	3	868	3
Black shale	23	8	891	11
Metal	0	9	892	8
Strong shale	20	1	912	9
Bass	1	8	914	5
Clod	4	11	919	4
Bass with stone	7	4	926	8
COAL	0	3	926	11
Stone	2	9	929	8
Metal	6	1	935	9
Rock	2	2	937	11½
Metal	6	0	943	11
Pricking	0	11	944	10
Bass	3	11	948	9
Metal	5	2	953	11
Bass	3	0	956	11

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
LITTLE MINE COAL	2	5	959	4
Pricking	1	4	960	8
Metals	12	6	973	2
Pricking	0	6	973	8
Fireclay	7	6	981	2
Metals	15	1	996	3
Rock	4	0	1,000	3
Metals	10	0	1,010	3
Rock	3	6	1,013	9
Metal	4	6	1,018	3
Fireclay	7	9	1,026	0
Warrant	11	0	1,037	0
Metals with stone	20	6	1,057	6
Rock	25	0	1,082	6
Metal	2	4	1,084	10
BAMBURY COAL	4	7	1,089	5
Pricking	5	0	1,094	5
Metal	11	2	1,105	7
COAL AND BASS	2	0	1,107	7
Metal	10	3	1,117	10
Soft metal	1	4	1,119	2
Rock	4	5	1,123	7
Metal	1	3	1,124	10
Stone	1	0	1,125	10
Metal and stone	4	1	1,129	11
Metal	5	6	1,135	5
Soft metal	2	11	1,138	4
Metal	36	9	1,175	1
Bass	4	11	1,180	0
Metal	7	3	1,187	3
Rock	2	0	1,189	3
Binds	15	0	1,204	3
Metal	20	0	1,124	3
Bass	5	4	1,229	7
Pricking	1	9	1,231	4
COCKSHEAD COAL	9	9	1,241	1
Warrant	6	7	1,247	8
Metal	2	5	1,250	1
Bass	1	4	1,251	5
Metal and rock	2	4	1,253	9
Rock	1	3	1,255	0
Metal	4	6	1,259	6
Bass metal and stone	18	0	1,277	6
Bass	4	0	1,281	6
Metal	9	0	1,290	6
Bass with shale	1	1	1,291	7
Bass	11	9	1,303	4
Metal	2	3	1,305	7
COAL	0	4	1,305	11
Metal	3	0	1,308	14
Hard rock	3	5	1,312	1
Metal	13	6	1,325	10

SECTION No. 10.

OLDFIELD No. 4, LONGTON.

O.D. 450 Feet (approx.).

From Mr. G. A. Mitcheson.

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
Made ground	7	0	0			
Gravel and soil	1	1	0			
Blue and red pebbly clay mixed	5	2	0			
Sandy clay (drift)	2	2	6			
Dark fine clay	1	1	6	18	1	0
COAL	0	0	6			
Fireclay	0	1	3			
Coal slum	0	0	3			
Fireclay	0	1	4			
COAL	0	0	3			
Fireclay	0	1	0			
Black ground	0	2	8			
COAL	0	0	6	21	1	3
Black ground	0	1	6			
Grey marl	4	1	3			
Coal slum	0	0	6			
Light-coloured binds	3	2	9			
Black ground	0	2	0			
Grey rock	1	0	0			
Fireclay with boulders of ironstone	4	0	0			
Grey sandstone	1	2	0			
Dark marl	4	1	0			
COAL	0	0	6	41	2	3
Good fireclay	3	1	6			
Strong clod	6	1	6			
Dark clod	0	1	4			
COAL	0	1	0			
Fireclay partings	0	0	2			
COAL	0	1	6			
Blue binds	7	0	0			
Peldon	0	1	6	60	1	9
Mottled marl	4	0	6			
Grey marl	1	1	0			
Red marl partings	0	0	2			
Light binds	2	1	10			
Very strong brown rock	0	1	6			
Mottled ground	5	2	6			
White marl	1	1	6			
White sandstone	0	2	0			
Rock binds	0	1	0			
Black bass	0	0	9			
Grizzly stone	0	1	7			
BASSEY MINE (Hollows)	0	0	9			
BASSEY MINE COAL	0	2	0			
Fireclay and boulders	3	2	0			
Strong good fireclay	4	0	6			
Dark fireclay	1	1	6			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
COAL	0	1	4			
Dark bat and binds mixed	1	1	2			
COAL	0	0	6			
Binds	3	0	6			
Fireclay	1	2	0			
PEACOCK COAL	0	2	6	95	1	10
Pricking	0	1	0			
COAL	0	1	6			
Fireclay	1	2	0			
Light-coloured binds	4	0	6			
Strong fireclay	3	1	0			
Binds containing balls of stone	1	2	6			
Light-coloured binds	1	1	0			
Strong brown rock	3	0	4			
Blue binds	3	0	9			
Mixed ground	4	0	6			
Binds	4	0	0			
SPENCROFT COAL	2	1	4			
Mixed ground, clod and bass	2	2	9			
Dark rock binds	0	2	2			
Strong brown rock	1	2	3			
Light rock binds	3	2	6			
Dark binds	3	2	9			
GREAT ROW COAL	2	2	0	142	0	8
Light fireclay, good	1	1	0			
Parting slum	0	0	2			
Dark fireclay	1	0	5			
Mixed ground—bass, coal, clay	2	2	3			
Peldon	0	2	0			
Mixed ground	2	2	0			
Black bass	1	1	0			
CANNEL ROW COAL	1	2	0	153	2	6
Slum and black fireclay	2	0	0			
Strong grey rock	4	1	0			
Dark fireclay	1	0	2			
Light fireclay	4	0	6			
Rock binds	1	2	6			
Black bass	0	1	0			
Black bass and ironstone	0	0	3			
Mixed fireclay and bass	0	2	6			
Bass and coal	0	2	6			
Strong fireclay and ironstone nodules	2	2	4			
Rock binds and mixed ground	4	0	5	176	0	8
Black bass	0	2	0			
WOOD MINE MEASURES: IRONSTONE	0	0	3			
Bass	0	3	6			
IRONSTONE	0	0	2			
Black bass	0	1	9			
IRONSTONE	0	0	2			
Black-jointed bass	0	3	11			
IRONSTONE	0	0	1			
Black bass	0	1	0			
COAL	0	1	3	180	2	9

Character of Strata.		Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
	Clod and clay	0	2	0			
	COAL	0	1	6	182	0	3
	Fireclay with boulders	1	1	0			
	Black parting	0	0	3			
	Dark fireclay with nodules	1	0	0	184	1	6
DEEP MINE	White ironstone	0	0	8			
DEEP MINE	Black clod with 2″ to 5″ of ironstone	2	0	0			
DEEP MINE	Bat	0	0	3			
DEEP MINE	COAL	0	2	0			
DEEP MINE	Fireclay pricking	0	0	1	187	1	6
	Strong light-coloured binds	1	1	0			
	Light rock binds	5	0	0			
	Strong brown rock	0	2	0			
	Dark rock binds	3	2	0			
	Light rock binds	4	1	8			
CHALKY MINE IRONSTONE	Light IRONSTONE	0	0	3			
CHALKY MINE IRONSTONE	Black bass	0	1	9			
CHALKY MINE IRONSTONE	,, IRONSTONE	0	0	2			
CHALKY MINE IRONSTONE	,, bass	0	0	6			
CHALKY MINE IRONSTONE	,, IRONSTONE	0	0	3			
CHALKY MINE IRONSTONE	,, bass	0	0	11			
CHALKY MINE IRONSTONE	,, IRONSTONE	0	0	3			
CHALKY MINE IRONSTONE	,, bass	0	0	10			
CHALKY MINE IRONSTONE	,, IRONSTONE	0	0	4			
CHALKY MINE IRONSTONE	,, bass	0	0	10			
CHALKY MINE IRONSTONE	,, IRONSTONE	0	0	2			
CHALKY MINE IRONSTONE	,, bass	0	0	10			
CHALKY MINE IRONSTONE	,, IRONSTONE	0	0	6			
CHALKY MINE IRONSTONE	,, bass	0	0	8			
CHALKY MINE IRONSTONE	COAL	0	1	1			
	Dark fireclay with ironstone nodules	1	1	10			
	Strong white fireclay with large boulders	2	0	0			
	Dark-coloured binds	3	0	4			
	Light rock binds with tar	4	0	8			
	Strong dark grey rock with tar	2	1	7			
	Blue clod	0	0	10			
	Brown rock	2	1	1			
	Coarse brown rock	2	1	11			
	Blue clod and binds	1	0	10			
	Beds of rock mixed with blue clod	0	2	10			
	Black bass mixed withcakes of ironstone	3	2	6			
	Grey ironstone	0	0	6			
	Clod	0	2	10			
	NEW MINE COAL	0	1	11	232	1	2
	Dark slum	1	2	10			
	Black clod	1	2	0			
	Grey rock	1	0	6			
	Grey clod	0	2	0			
	Grey mild rock	0	2	6			
	Dark clod and bass	1	1	0			
	Brown open rock	1	0	0			
	Clunch	1	2	7			
	Black bass mixed with thin ironstone	2	1	5			

Character of Strata.		Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
HANBURY MINE COAL		0	0	9	247	1	4
	Clunch with rock boulders	2	1	8			
	Bass and bat	0	1	6			
	Fireclay	0	2	0			
COAL		0	1	3			
	Black slum	0	1	0	251	2	9
	Clunch	1	0	5			
	Mild rock	2	1	8			
	Strong rock binds	1	0	0			
	Fireclay parting	0	0	1	256	1	11
BAY MINE, IRONSTONE	Black bass	0	0	10			
	IRONSTONE	0	0	5			
	Bass	0	0	8			
	IRONSTONE	0	0	4			
	Bass	0	0	2			
	IRONSTONE	0	0	2			
	Bass	0	0	5			
	IRONSTONE	0	0	4			
	Bass	0	0	7			
	IRONSTONE (irregular)	0	0	2			
	Bass	0	0	9			
	IRONSTONE bands	0	0	10	258	1	7
	Clunch	2	2	6			
	Grey rock	1	1	8			
	Brown rock	1	0	1			
	Rock binds	7	0	6			
	Black bass with nodules of ironstone	3	2	6			
	Bass	2	1	0			
BAY COAL		0	2	1			
	Clunch	0	2	6			
	Rock with 3″ to 4″ parting of clunch	5	0	3			
	Clunch	1	2	0			
	Blue binds	0	2	0			
	Black slum with nodules of ironstone	0	2	6			
	Clunch with few nodules of ironstone	3	2	9			
KNOWLES COAL		1	2	7	292	2	6
		0	1	9			
	Bass	1	0	11			
	Clunch	1	2	7			
	Binds	1	2	10			
	Bass with ironstone bands	1	0	5			
	Strong binds with rock partings	7	2	8			
PRIORSDALE BASS		7	2	6	315	1	5
	Rock	0	0	8			
	Bat	0	0	3			
	Clunch	5	1	9			
	Rock	0	1	0			
	Clunch	1	2	10			
	Bed of rock with bind partings	5	1	11	329	0	10
KNOWLES IRONSTONE	Bass	0	2	1			
	IRONSTONE	0	0	2			
	Bass	0	3	1	330	2	4
	IRONSTONE (irregular)	0	0	2			

Character of Strata.		Thickness.			Depth.		
		Yd.	Ft.	In.	Yd.	Ft.	In.
KNOWLES IRONSTONE	Bass	0	1	0			
	IRONSTONE (irregular)	0	0	2			
	Bass	0	1	7			
	IRONSTONE	0	0	4			
	Bass	1	1	0			
	IRONSTONE	0	0	11			
	Bass	1	0	1			
	IRONSTONE	0	1	3			
	Bass	1	2	4			
	IRONSTONE	0	0	2			
	Bass	0	2	7			
	IRONSTONE (irregular)	0	0	2			
	Bass	1	1	0			
	IRONSTONE (irregular)	0	0	3	339	1	2
	Sharp bat	0	1	5			
COAL		0	1	3	340	0	10
Bat		0	1	2			
Clunch		0	1	0			
Bat		0	0	6			
COAL		0	1	4			
Bat and coal		1	1	9			
Black slum		0	2	4	343	2	11
IRONSTONE		0	0	2			
Bass		0	1	0	344	1	1
IRONSTONE		0	0	2			
Black bass and clod		0	2	0			
IRONSTONE		0	0	6			
COAL		0	0	9			
Clunch		3	0	5			
Binds		1	2	8			
Rock binds		2	1	8			
Strong grey sandstone (Ash rock)		28	1	7			
Black shaly bass		4	0	2	385	2	0
RIDER COAL		0	2	6			
Bat		0	0	2			
COAL (inferior)		0	0	6	386	2	2
Black shale		0	0	5			
Clunch with slum		2	1	1			
Bind containing bed of rock		2	1	4			
Black bass		0	1	2			
Black slum		0	0	2			
ASH COAL		2	0	4	394	0	8
Fireclay		0	1	0			
Clunch		6	2	2			
Bat		1	0	9			
Blue binds		9	0	8	411	2	3
Rock		0	2	0			
Strong binds		3	0	8			
Fireclay		0	0	5			
Blue binds		1	2	0			
Bass with cakes of ironstone		1	2	1			
Bass and *Coal*		0	0	8			
Black bat		1	2	6			

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
Glunch	1	0	6			
Shaly bass	0	2	1			
IRONSTONE	0	0	3			
Bass	0	1	4			
LITTLE MINE COAL	0	2	2	424	0	11
Bat	0	0	7			
Soft fireclay	0	0	2			
Glunch with many boulders	2	0	4			
Mild rock	7	0	0			
Fireclay with ironstone pebbles	2	2	5			
Marl partings	0	0	11			
Fireclay with ironstone pebbles	4	1	5			
Clunch and fireclay mixed	2	0	0			
Rock, mixed and irregular	0	2	6			
Rock, mottled red and grey	6	1	10			
Mottled marl	0	1	0			
Bass	1	0	0			
Binds	3	0	3			
Rock (all in one bed)	2	2	9			
Beds of rock with bind partings	2	1	10			
Bat	0	0	8			
Bass	13	1	9			
DOCTORS MINE COAL	0	1	9	475	0	6
Bat	0	0	2			
Fireclay with stone	3	0	6			
Bat mixed with clay	1	0	0			
Dark shale	0	0	4			
Fireclay	3	2	8			
Binds	1	1	0			
Beds of rock	1	1	4			
Binds	3	1	6			
Metal and strong binds	5	2	7			
Shale	0	1	0			
Bass	1	1	8			
Shale	0	0	10			
Grey bass	0	1	0			
Blue binds	3	2	3			
Dark binds	2	0	2			
COAL	0	0	9			
Clunch	2	1	6			
Strong fireclay	2	2	0			
Bass with thin cake of ironstone	5	0	5			
Clunch	0	2	2			
Coal streaked with bat	0	0	9			
COAL	0	1	4			
Rock	0	0	1			
Black shale	0	0	3			
Fireclay	1	1	4			
Strong binds	3	2	0			
White rock	5	1	0			
Strong binds	0	1	0			
Strong binds with boulders of rock	3	0	4			
Rock	5	0	3			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Strong binds, called "*Moss Metals*"	4	2	1	539	1	9
Grey bass	1	0	5			
Black bass	1	1	5			
Strong binds, called "*Moss Metals*"	5	1	6			
MOSSFIELD COAL	1	0	9	548	2	10
Dark bat	0	0	9			
Dark clunch	1	0	9			
Bass	0	2	0			
Light-coloured clunch	1	2	7			
Black bat and dark ground	1	2	6			
CANNEL COAL	0	2	1	555	1	6
Clunch	1	2	8			
Dark clunch with stones	0	1	10			
Rock	1	2	1			
Binds	4	0	0			
Bass	0	1	8			
Bat and *Coal*	0	0	11	565	0	7
Fireclay	0	1	0			
Bat and *Coal*	0	0	11			
Clunch	8	0	1	573	0	8
Binds	2	2	0			
Rock	0	1	0			
Binds with beds of rock	1	2	2			
Rock in beds with partings	3	1	3			
Binds	3	1	5			
Beds of rock with binds	0	1	9	601	2	11
Rock	1	1	3			
Binds	2	0	10			
Rock with thin bind partings	2	2	5			
Strong grey binds	2	1	7			
Soft binds and thin beds of rock	6	2	0	601	1	2
Rock	0	1	9	601	2	11
Rock with bind partings	9	2	8			
Binds	3	2	4			
Rock	1	2	0			
Bass	1	2	10			
COAL	0	2	7	620	0	4
Soft fireclay	0	1	0			
YARD COAL { COAL	1	1	0			
YARD COAL { Fireclay	0	2	2			
YARD COAL { COAL	0	2	2			
Fireclay	0	1	3	623	1	11
Rock	3	1	7			
Blue binds	8	1	5			
Bass and shale	1	1	7			
Strong binds (metals)	1	0	6			
Black bat	1	1	7			
Clunch	1	0	10	641	0	5

SECTION No. 11.

SECTION OF No. 3 SHAFT, GLEBE COLLIERY, FENTON.

O.D. 480 Feet.

From Mr. J. Ashworth.

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
Made ground	4	1	6			
Soil	0	1	9			
Clay	1	0	3			
Yellow marl	0	2	3			
Yellow rock	3	1	3			
Blue rock	6	0	0			
Grey marl	1	1	9			
Red marl	4	0	3			
Red and mixed marl	6	0	9			
Blue rock	7	1	6			
Red and mottled marl	11	1	0			
COAL	0	0	6	47	1	0
Soapy metal	1	1	3			
COAL	0	0	9	49	0	0
Fireclay Parting	0	1	3			
GUTTER OR STOKESLEY COAL	0	1	10	50	1	1
Fireclay	1	2	1			
COAL	0	0	3			
Strong grey marl	0	2	0			
Grey metal	1	0	10			
COAL	0	0	6			
Strong grey marl	2	0	6			
Strong grey rock	1	1	0			
Grey marl	1	0	8			
Red and mingled marl	6	1	1			
Dark grey marl	3	0	3			
HALF YARDS COAL	0	2	0			
Warrant fireclay	0	2	0			
Strong grey marl	4	1	9			
Soft light marl	0	0	9			
Strong light metal and bands of stone	3	0	3			
Light coloured metal	1	2	8			
COAL	0	0	4			
Warrant earth	0	1	6			
COAL	0	0	6			
Warrant earth with light soft shaly marl	1	2	6			
COAL	1	0	0	82	2	6
Fireclay warrant	1	0	6			
Grey marl	2	1	0			
Red and mottled marl	10	2	9			
Dark marl	1	1	0			
COAL	0	0	4			
Dark shaly marl	0	2	11			
COAL	0	1	0			
Fireclay mixed with shale	4	1	0			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
COAL	0	0	4			
Fireclay mixed with shale	0	2	8			
Mush of coal	0	0	3	105	1	3
Dark fireclay mixed with shale	0	1	5			
COAL	0	0	9			
Warrant earth	0	0	9			
Grey rock	4	1	10			
Irregular ground, marl, metals, and balls of ironstone	16	0	6			
Strong bass interlined with spar	0	1	8			
Metal	0	0	10			
Dark streaky bass	0	0	8			
Strong warrant mixed with rock and metals	8	1	10			
Dark strong bass with 6″ ironstone band	0	1	6			
COAL	0	2	3			
Fireclay warrant	1	1	6			
Top Main Fault.						
Light marls	5	0	9	144	2	6
Strong dark rock	0	1	0			
Irregular ground in fault	16	0	6			
Fault goes out in south side.						
Strong light metals	2	1	0			
Strong grey rock	10	2	0			
Strong light metals	0	2	0			
Black bass	1	0	0			
Fault shown S., goes out in S. side.						
Irregular ground, metals, etc.	12	0	0			
Grey rock	0	2	0			
Grey metals	4	0	0			
Black bass with balls of stones	4	2	2			
COAL	0	0	10			
Fireclay	0	2	0			
COAL	0	1	0			
Hard warrant	1	1	0			
Metals and rock binds	7	0	3	207	0	3
COAL	0	0	4			
Clunch	0	1	7			
COAL	0	1	0			
Strong warrant	1	0	10			
Rock binds	2	0	0			
Metals	0	2	0			
Black bass	0	2	3			
IRONSTONE	0	0	3			
Flag	0	1	0			
IRONSTONE	0	0	2			
Flag	0	0	11			
IRONSTONE	0	0	4			
Flag	0	0	6			
IRONSTONE	0	0	2			
Bass with balls of ironstone	0	2	0			
Rock	0	0	7			
Metals	0	2	10			
Rock binds	4	0	6	219	2	6

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
Strong grey rock	3	0	6			
Strong grey metals	7	2	0			
Black bass	3	0	0			
Light metals	1	2	0			
BAY OR LADY COAL ? { COAL, Ft. 1 In. 6; Dirt, 0 1; COAL, 0 6 }	0	2	1			
Rock binds	1	0	6			
Knowles rock—strong grey	6	2	5			
Strong metals with stone balls	10	0	0			
KNOWLES COAL	2	2	0			
Black shaly bass	1	1	0			
Fireclay warrant	1	1	0			
Strong metal with bands of rock	5	0	2			
Rock	0	2	0			
Black bass with bands of ironstone	2	1	0			
COAL	0	0	7			
Strong rock binds with peldon	2	1	9			
Black metal with cakes of ironstone	8	2	6	279	0	0
Dark bass with bands of ironstone	2	1	10			
COAL	0	0	1			
Clunch	3	0	5			
Band of rock	0	1	6			
Marl	1	0	6			
Rock or rock bands	6	1	8			
Light metals	2	2	0			
Dark bass with ironstone bands (? *Knowles Ironstone.*)	8	1	6	304	0	6
COAL	0	0	6			
COAL and slag	0	2	2			
COAL	0	0	10			
Strong warrant	2	0	0			
Clunch	2	0	0			
Dark shale	1	0	0			
Clunch	1	1	0			
BLACK MINE IRONSTONE	2	1	0	314	0	0
COAL	0	0	6			
Strong warrant	5	1	6			
Rock binds	5	1	0			
Metals and shales	2	2	0			
Rock and rock binds	3	0	0			
Strong light metals	12	0	6			
Dark bass with ironstone	0	1	6			
Strong dark metals with ironstone	5	1	0			
RIDER COAL	0	2	10			
Slag	0	0	3			
Inferior coal	0	0	8	349	2	9
Strong warrant	2	0	3			
Band of grey rock	0	2	0			
Ash Coal roof-clod and streaked metals	1	2	0			
ASH COAL	2	1	0			
Ash warrant	3	0	0			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Black marl with streaks of coal and ironstone nodules	1	2	0			
Strong metals	11	1	0			
Dark rock with spar	0	1	6			
Strong metals	4	0	6			
Ironstone measures-clod	0	1	9			
IRONSTONE	0	0	3			
Clod	0	1	6			
IRONSTONE	0	0	3			
Clod	1	1	0			
Coal (inferior) and bass	0	2	3			
Strong clod	2	1	0			
LITTLE MINE IRONSTONE	0	1	3			
LITTLE MINE COAL	0	2	3			
Slag	0	0	7			
Holing dirt	0	0	3			
Strong light warrant and bands of rock	3	1	11			
Fireclay rock	2	2	0			
Strong dark metals	2	0	0			
Strong grey rock	21	1	0			
Rock and grey metal	1	0	0			
GIN MINE COAL	0	2	6	417	0	6
Warrant rock	0	0	8			
Strong metals	1	0	4			
Strong grey rock	6	2	6			
Grey metals	2	0	6			
Grey rock	1	1	6			
Metals and rock binds	6	0	0			
Black metal	7	1	0			
COAL and bass	1	0	0	443	1	0
Strong fireclay	1	2	0			
Rock binds and metals	21	2	0			
Blue metals	10	2	0			
Black bass	0	1	0			
IRONSTONE	0	0	4	477	2	4
Black bass	0	2	6			
IRONSTONE	0	0	3			
Black bass	0	1	11			
IRONSTONE	0	0	3			
Black bass	1	0	6			
COAL and bass	0	1	3	481	0	0
Strong warrant	1	0	0			
Sandstone, grey and red—very strong with	13	0	0			
Dark bass and metals, balls and cakes of ironstone	14	0	2			
COAL	0	1	10			
Marl and fireclay	5	1	0			
Strong blue metals	11	0	0			
Black mush	0	1	0			
Black bass	0	2	3			
Band of rock	0	0	6	527	0	9
Rock binds	11	0	6			
COAL	0	0	9			
Clunch and metals	10	0	0			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Black shale	0	2	0			
Black shale and clunch	5	0	6			
BIRCHENWOOD COAL { COAL	0	1	11	555	0	5
BIRCHENWOOD COAL { Strong warrant	2	0	4			
BIRCHENWOOD COAL { COAL	0	1	3			
Clunch	2	0	0			
Blue metals	3	2	6			
Band of stone	0	0	1			
Dark metals	0	2	6			
Band of stone	0	0	1			
Dark mush	0	0	4			
Clunch	0	1	2			
Rock binds	1	1	4			
Soapy metals	15	0	3			
Cannel	1	0	0	582	1	3
Holing dirt	0	1	3			
Pricking	0	0	2			
MOSSFIELD COAL	1	0	10	584	0	6
Strong warrant	3	1	10			
Dark cannelly bass	0	2	8			
COAL	0	2	0			
Black slag	0	0	4			
Clunch	2	2	8			
Rock bands	0	1	6	592	2	6

SECTION No. 12.

OLDFIELD COLLIERY, No. 3 PIT.

O.D. 450 Feet (approx.).

From Mr. G. A. Mitcheson.

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Pit mound	5	1	0			
Soil	0	0	9			
Marl with pebbles	6	2	6			
Dark fireclay	1	0	6			
COAL	0	1	6	14	0	3
Dark fireclay	0	2	3			
Black bat and coal mixed	0	1	7			
Dark fireclay	1	1	0			
Strong light blue binds	6	0	2			
COAL	0	0	4	22	2	1
Strong light blue binds	5	2	0			
Black bat	0	0	2			
Strong light blue binds mixed with balls of stone called "cank"	3	0	6			
Dark fireclay mixed with layers of coal	2	1	0			
Grey rocky fireclay—very strong	3	0	0			
Light blue binds	1	2	0			
Dark fireclay with shreds of coal mixed	1	0	6			

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
COAL - - - - - - - - - - -	0	0	9	60	0	6
Dark fireclay - - - - - - - -	1	2	0			
Strong grey fireclay, rocky and mixed with balls of rock - - - - -	6	1	0			
Black bat- - - - - - -	0	0	2			
Strong light blue binds mixed with ironstone -	4	0	0			
Black bat mixed with studs of coal - -	0	1	0			
Light fireclay - - - - - - - -	0	0	3			
COAL - - - - - - - - -	0	2	0	53	0	11
Light blue fireclay - - - - -	0	2	0			
Strong brown fireclay mixed with balls of rock -	1	1	0			
Strong light blue rock binds mixed with balls of rock - - - -	4	0	0			
Dark grey "peldon" or "cank" - -	0	1	0			
Fireclay with rock balls - -	3	2	0			
Dark fireclay -	1	1	0			
Strong dark rock binds -	3	1	0			
Dark grey peldon -	0	2	0			
Strong dark grey binds	1	2	0			
Dark rocky fireclay -	2	2	0			
Dark rock binds -	3	2	0			
Strong black bat -	1	2	0			
BASSEY MINE IRONSTONE	0	2	0	78	2	11
BASSEY MINE COAL - -	0	2	6			
Soft dark fireclay - - -	1	0	0			
Light strong rocky fireclay -	5	1	0			
COAL - - - - -	0	1	8	86	2	1
Dark fireclay - - -	0	2	9			
Strong, light fireclay -	1	2	0			
Dark fireclay - - -	0	1	0			
Strong brown fireclay mixed with balls of rock -	3	1	6			
Dark blue binds - - -	0	2	0			
Soft black bat -	0	0	3			
Dark blue binds -	0	0	9			
Soft, dark bat -	0	0	6			
Dark blue binds	0	1	6			
PEACOCK COAL -	0	2	10	95	2	2
Dark fireclay -	0	0	9			
COAL - -	0	0	9			
Soft, dark fireclay -	1	1	0			
Light brown, very good fireclay- - - -	2	1	0			
Strong brown rocky bands with cank balls -	3	2	0			
Dark soft bind - - - -	0	0	9			
Black bat with coal shreds- - -	0	0	1			
Light blue binds - - -	0	0	6			
Soft black bat mixed with coal shreds-	0	2	6			
Strong dark grey rock - -	1	2	0			
Very strong light grey rock with cank balls-	2	1	0			
Cank or peldon - - - - - -	3	0	0			
Strong light grey rock - - - -	1	2	0			
Soft dark binds - - - - - -	1	0	0			
Black bat - - - - - -	0	0	6			
Soft dark binds- - - - -	0	1	6			

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
Soft black bat	0	0	4			
Dark soft binds	0	2	6			
Black bat	0	0	4			
Dark fireclay	0	1	6			
Soft dark binds mixed with coal shales	2	1	0			
Soft black bat	0	0	6			
Dark blue binds	0	1	9			
Dark binds with shreds of coal	0	2	9			
Very strong black bat	0	2	0			
Dark fireclay	0	0	9			
SPENCROFT COAL	1	0	9			
Dark fireclay mixed with coal shreds	0	2	3			
COAL	0	2	0			
Dark fireclay mixed with coal shreds	0	2	0			
COAL	0	1	9			
Dark fireclay mixed with coal shreds	0	1	6			
Soft black bat	0	1	3			
COAL	0	1	6			
Dark fireclay	0	1	6			
Very strong grey rock	1	0	6			
Cank or peldon	2	1	0			
Strong blue bind	2	2	0			
GREAT ROW COAL	2	0	0	135	1	11
Dark brown fireclay	1	1	0			
Dark fireclay with shreds of coal	0	0	9			
Dark fireclay	1	2	0			
Dark fireclay with shreds of coal	1	0	0			
Dark blue binds mixed with coal shreds	3	1	6			
Cank or peldon	0	1	6			
Dark brown fireclay	3	0	0			
Black bat	0	2	4			
CANNEL ROW COAL	1	1	6	149	0	6
Dark studdy bat	0	0	9			
Dark brown fireclay	0	0	3			
Coal and black bat mixed	1	0	0			
Dark brown fireclay	0	0	9			
Very strong brown rock	2	0	0			
Cank or peldon	3	0	0			
Strong dark binds	0	2	6			
Dark soft binds	0	1	2			
Very strong rock binds	2	0	0			
Dark binds with cank balls	1	1	0			
Strong brown fireclay	1	2	0			
Very strong dark rock with cank balls	1	1	6			
Dark binds	0	2	0			
Soft black bat with coal shreds	1	0	6			
Very strong rock binds with rock balls	5	0	9			
Very strong black bat with ironstone balls	4	1	0			
WOOD MINE COAL	0	1	0	175	0	8
Dark shreddy bat	0	2	0			
Coal and bat mixed	0	1	3			
Dark brown fireclay	1	2	6			
Black fireclay	0	1	6			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd	Ft.	In.
Strong light brown fireclay	0	2	6			
Soft black bat	1	1	6			
DEEP MINE IRONSTONE	0	0	3	181	1	6
Strong black bands	0	1	6			
Balls of ironstone 4″ to 6″	0	0	5			
Strong black binds	0	1	6			
Ironstone-irregular	0	0	3			
Strong black binds	0	1	10			
DEEP MINE COAL	0	2	9			
Light brown fireclay	0	2	0			
Dark fireclay with shreds of coal	0	0	9			
Light strong fireclay	0	1	6			
Strong rock binds	1	0	0			
Very strong grey rock	3	1	0			
Very dark rock binds	1	0	0			
Black bat	0	0	9			
Dark strong rock binds	2	0	6			
Strong dark grey rock	4	0	0			
Strong dark grey binds	1	1	6			
Strong black bat	2	1	6			
Strong dark blue binds	0	2	6	202	0	9
CHALKY MINE IRONSTONE. { IRONSTONE	0	0	1½			
Black shale	0	2	6			
IRONSTONE	0	0	1½			
Strong black bat	0	2	3			
IRONSTONE	0	0	2½			
Strong black bat	0	1	5			
IRONSTONE	0	0	3			
Black bat	0	0	9			
COAL	0	0	11	205	0	4
Dark fireclay	0	0	6			
Light brown fireclay	0	0	9			
Strong brown fireclay with ironstone nodules	0	2	0			
Strong rocky brown fireclay mixed with rock balls	0	2	0			
Very strong dark rock binds mixed with cank balls	4	1	6			
Strong binds	4	1	7			
Strong grey rock	1	2	7			
Coarse brown rock	6	1	7			
Blue clod	1	1	5			
Strong grey rock	0	2	5			
Black bass	0	2	9½			
Bass with cake of ironstone	3	0	0			
Grey clod	0	2	5			
NEW MINE { IRONSTONE	0	0	8			
Bass	0	0	4			
COAL	0	1	8	231	1	5½
Dark slum	2	1	1			
Clunch	0	0	11			
Rock	0	2	2			
Clunch	3	2	10			
Brown rock	0	2	0			
Black slum	0	0	6			
Fireclay and beds of rock	1	1	1			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Clunch and beds of rock	0	2	0			
Bass with irregular bands of ironstone	4	1	11			
HANBURY MINE COAL	0	0	11	246	1	10
Clunch	1	0	0			
Rock	0	1	3			
Strong binds with balls of rock	0	1	7			
COAL	0	0	9			
Black bat	0	0	8			
Clunch	5	2	4			
Fireclay and stones	0	2	7			
RAGMINE COAL	1	0	3	256	2	3
Clunch	3	2	8			
Grey rock	0	2	0			
Brown rock	2	0	7			
Rock binds	6	2	0			
Black bass with few cakes of ironstone	0	2	6			
Black bass	5	0	10			
Dark clod	1	0	10	278	0	10
BAY COAL	0	1	8			
Dark clod	0	1	0			
Mild grey rock	1	0	0			
Marl	0	0	3			
Grey rock	1	2	2			
Clunch mixed with bands of rock	2	2	10½			
Clunch with cakes of ironstone	6	0	2			
KNOWLES ROOF COAL	0	2	6			
KNOWLES COAL (hollows)	0	2	4			
Bass	1	0	0			
Clunch	1	1	0			
Mild binds	2	0	4			
Bass with ironstone balls	1	0	5			
Clunch	3	0	4½			
Strong rock binds	5	2	6			
PRIORSFIELD BASS	8	1	0			
Rock	0	0	8			
Clunch	2	1	1			
Rock with bind partings	4	2	3			
KNOWLES IRONSTONE: Knowles bass	1	0	3			
IRONSTONE	0	0	3			
Bass	0	0	8			
IRONSTONE	0	0	3			
Bass	0	1	10			
IRONSTONE	0	0	3			
Bass	0	1	0			
IRONSTONE	0	0	3			
Bass	0	0	9			
IRONSTONE	0	0	1			
Bass	0	1	8			
IRONSTONE	0	0	3			
Bass	0	0	3			
IRONSTONE	0	0	3			
Bass	1	0	5			
IRONSTONE (irregular)	0	0	8			

Character of Strata.		Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
KNOWLES IRONSTONE	Bass	0	2	6			
	IRONSTONE	0	0	10			
	Bass	0	1	9			
	IRONSTONE	0	0	2			
	Bass	0	1	3			
	IRONSTONE	0	0	6			
	Bass	1	2	10			
	IRONSTONE	0	0	2			
	Bass	0	1	11			
Strong bass		0	0	10			
Bat and coal		0	2	5			
Bass		0	0	10			
Clunch		0	1	4			
Bat and coal		0	2	6			
Pricking		0	0	2			
Bat and coal		0	2	0			
Pricking		0	0	7			
Bat and bass		1	1	5			
Ironstone		0	0	2			
Bass		1	0	2			
Ironstone		0	0	6			
COAL		0	0	8			
Bat		0	1	6			
Fireclay mixed with chunks of coal		0	0	11			
Clunch		3	2	9½			
Very strong rock		33	0	10			
Shaly bass		0	2	10			
RIDER COAL		0	2	0	383	2	10½
Bat		0	0	3			
COAL		0	0	5			
Dark shaly warrant		0	0	5			
Clunch		2	1	2			
Rock and binds mixed		2	0	10			
Black bass		0	2	8½			
ASH COAL		2	0	4	392	0	0
Fireclay		0	1	0			
Clunch with stones		8	1	2			
Bat		0	1	2			
Blue binds		9	2	3½			
Very hard rock		1	1	3			
Blue binds and marl partings		5	0	11			
Bass, bat, a little coal, and cakes of ironstone		2	0	0			
Clunch		0	1	3			
Bat		1	1	0			
Clunch		0	2	9			
Bass and clunch		1	0	2			
Ironstone		0	0	7			
Bass		0	1	1			
LITTLE MINE COAL		0	2	5			
Bat		0	0	6			
Clunch with rock boulders		4	1	8			
Very strong clunch with beds of rock		2	2	4			
Bat		1	1	4			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Strong fireclay with hard cake of rock	4	0	1			
Bed of close grained rock with strong binds	6	1	8			
Very strong mottled rock with small cakes of ironstone	2	2	4			
Very strong grey rock streaked with red crystals	3	0	2			
Grey and red rock mixed with very hard crystals	1	2	0			
Mottled marl with small thin cakes of ironstone	2	0	9			
Strong black bass	2	1	5			
White rock with thin bind partings	2	2	11			
Black bass with cakes of ironstone	4	2	6			
Black bass full of small slips	2	2	6			
Black bass	6	2	9			
DOCTORS MINE COAL	0	1	7			
Bat	0	0	2			
Fireclay with stones	2	1	8			
Bat mixed with coal	1	0	0			
Dark shale	0	0	6			
Fireclay	3	0	8			
Binds	2	0	0			
Sandstone rock	2	1	0			
Binds	9	0	8			
Shaly bass	0	0	6			
Bass with cakes of ironstone	1	2	1			
Soft shale	0	1	3			
Grey binds	6	2	2			
COAL	0	0	11			
Bat	0	0	10			
Fireclay mixed with stone	2	2	0			
Bass in a fault	0	2	0			
Fault.						
Clunch	0	2	3			
COAL	0	2	2	499	0	10
Clunch	1	0	7			
Grey rock with water	11	0	3			
Binds with rock boulders	0	2	0			
Binds	2	1	0			
Beds of rock with bind partings	2	1	1			
Strong binds	0	2	8			
Rock	0	1	8			
Strong binds	0	2	2			
Mild binds	0	2	1			
Strong binds	5	1	5			
Bass	1	1	5			
Strong binds	5	1	8			
Grey bass	0	0	10			
Black bass with cannel	0	2	7			
Flaking bass mixed with fireclay	0	0	9			
MOSSFIELD COAL	1	0	9	535	0	0
Strong dark bat	0	0	9			
Dark clunch with pebbles	4	0	7			
CANNEL COAL	0	0	5	543	0	0
COAL	0	1	6			
Bass	0	0	5			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Strong fireclay and clunch - -	1	1	5			
Dark grey bass with bands of rock - -	0	1	9			
Binds of rock - -	1	1	0			
Grey binds -	2	2	0			
Strong binds - -	1	2	0			
Mild binds - -	2	1	5			
Dark binds with cakes of ironstone	0	1	7			
Black bass - - - - -	0	1	6			
COAL - - -	0	0	10			
Fireclay streaked with coal	0	1	1			
Bass and coal mixed -	0	0	9			
Clunch - -	0	2	10			
Fireclay with boulders	1	1	6			
Strong fireclay with rock boulders	3	0	7			
Binds with rock boulders -	3	2	6			
Beds of rock with bind parting	2	2	9			
Binds - -	1	1	6			
Rock	0	1	9			
Strong binds - -	2	2	1			
Binds with boulders - - -	2	0	0			
Strong binds with beds of rock	1	1	7			
Binds - -	0	1	4			
Rock -	3	0	1			
Rock in beds with bind partings -	2	2	8			
Binds mixed with boulders -	2	2	9			
Rock -	0	2	3			
Strong binds - -	1	2	10			
Binds containing bands of rock -	1	1	6			
Bed of rock - - - - -	0	1	0			
Strong binds -	1	0	2			
Rock - -	10	2	10			
Binds with bed of rock -	3	0	0			
Rock - - -	2	2	8			
Black bass -	0	4	10			
YARD COAL: COAL - -	0	2	6	611	2	2
YARD COAL: Fireclay, soft - -	0	1	0			
YARD COAL: COAL - - - -	1	1	2			
YARD COAL: Fireclay - - - -	0	2	5			
YARD COAL: COAL - - - - -	0	2	9			
YARD COAL: Fireclay - -	0	1	1			
Rock - - - - - -	3	1	7			
Blue binds with thin bands of rock - - -	8	1	10			
Bass full of slips - - -	2	0	1			
Strong binds with thin bands of rock -	0	2	10			
Black bat with streaks of coal - - - -	1	2	11			
Clunch and binds - - -	0	2	0	641	0	5

SECTION No. 13.
BROWNFIELD COLLIERY, DIVIDY LANE.
O.D. 590 feet.
From Mr. J. Ward.

Character of Strata.	Thickness.			Depth.		
	Yd.	Yt.	In.	Yd.	Ft.	In.
Soil and clay -	0	2	6			
Rock - - -	1	1	0			
Blue marl with band of ironstone	2	2	3			
Dark grey marl- -	9	1	0			
Grey bass	1	1	6			
Black clunch -	3	1	4			
Dark bass	0	1	6			
Light clunch -	0	1	3			
Rock	0	0	10			
Black clunch -	2	0	5			
COAL - - -	0	0	6			
Grey clunch	2	1	0			
Light strong bass -	2	2	0			
Black bass - -	1	0	4			
Marl -	1	0	0			
Bass with two bands of ironstone	1	1	3			
LITTLE MINE COAL - -	0	2	3	32	2	5
Clunch - -	0	1	2			
Rock -	0	1	4			
Dark strong clunch	4	1	7			
Light soft marl	1	0	8			
Rock and binds	3	2	1			
Peldon rock - - -	0	1	6			
Rock binds with bands of brown stone	9	2	7			
Gravel bed -	0	1	4			
Black shaly marl mixed with veins of coal -	0	2	3			
Marl - -	1	2	3			
COAL - -	0	0	4			
Clunch mixed with small stone - -	1	1	0			
Clunch with bands of red stone -	15	1	6			
BANBURY COAL - - - - -	1	1	0			
Shaly marl - - - -	0	1	8			
Grey clunch - -	4	1	0			
Black bass -	0	2	6			
Grey clunch - - -	4	1	6			
Rock - - - - - - -	0	2	0			
Blue clunch -	3	0	10			
Shaly bass -	0	1	10			
Grey clunch with bands of stone - -	11	0	8			
Bass - - - - -	1	1	6			
Clunch - - - -	0	2	6			
Rock - - - - - -	1	0	7			
Grey clunch - - - -	12	0	3			
Bass with bands of ironstone - - -	1	1	0			
Dark marl - - -	0	0	3			
Coal - - -	0	0	8			
Shale - - - - - -	0	1	0			
COCKSHEAD COAL - - - - - -	2	2	0	122	0	9

SECTION No. 14.

SHAFT AT UPPERHOUSE FARM, WERRINGTON.

O.D. 740 feet (approx.).

From Mr. J. R. Haines.

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Good brick clay	3	0	0	3	0	0
Grey marl	1	1	0	4	1	0
Red marl mixed with blocks of ironstone	4	1	6	8	2	6
Hard stone	0	1	0	9	0	6
Light grey marl with pebbles	1	1	0	10	1	6
COAL AND BASS	0	1	4	10	2	10
Dark grey marl	1	0	0	11	2	10
Hard stone -	0	1	3	12	1	1
Red marl / Ironstone	0	1	4	12	2	5
Grey marl	1	1	0	14	0	5
COAL AND BASS	0	0	7	14	1	0
Dark grey marl	0	2	6	15	0	6
Good red marl	4	1	0	19	1	6
Very hard rock	0	2	9	20	1	3
Grey marl mixed with sandy stones	2	1	6	22	2	9
Good red marl with blocks of red sandstone	9	2	0	32	1	9
Strong black bass, fine and clear	13	0	0	45	1	9
Black bass with hard and heavy blocks of iron stone	3	1	0	48	2	9
COAL (good) -	1	1	0	50	0	9
Dark fireclay	1	1	0	51	1	9
Red marl	4	2	0	56	0	9
Detailed section of Coal:—						
Top coal	0	1	6			
Fireclay (parting) - -	0	0	3			
Middle coal	0	1	4			
Fireclay (parting) - -	0	0	3			
Bottom coal -	0	1	0			

SECTION No. 15.

SHAFT AT UPPERHOUSE, WERRINGTON.*

O.D. 740 feet (approx.).

Character of Strata.	Thickness.		
	Yd.	Ft.	In.
Shale containing *Lingula, Discina* and *Goniatites*: from surface to bottom of COAL (including 2½ inches of clay in the centre)			
Strong red marl - -	5	0	0
White sand rock, mixed with quartz	6	1	0
Red rock - - - - -	2	0	0
Grey rock - -	2	0	0

* "The Geological Features of the North Staffordshire Coal-fields," J. Ward, *Trans. North Staff. Inst. Min. and Mech. Eng.*, vol. x.

This section is evidently a continuation of Section No. 14, in which the "red marl," the top of which is at a depth of 51 yards 1 foot 9 inches, is the "strong red marl" at a depth of 52 yards in the present section.

Character of Strata.	Depth.		
	Yd.	Ft.	In.
Soft metal	0	0	10
Grey rock -	0	1	0
Strong metal - -	0	1	0
Strong rock binds	1	1	0
Reddish-grey metal - - -	3	2	0
Shale (slums) -	0	0	10
COAL -	0	0	10
Grey rock - -	0	0	5
Shaly bass	3	2	0
Dark shaly bass -	2	1	6
Strong grey rock	2	2	0
Brown rock binds	0	1	6
Grey rock binds -	0	1	0
Grey rock	0	1	6
Brown rock binds - -	0	2	0
Grey rock -	0	0	6
Red rock	1	2	1
Brown rock	0	1	0
Grey rock	0	2	0
Red, brown, and grey rock	2	2	0
	90	1	0

SECTION No. 16.

RACECOURSE PITS, SHELTON.

O.D. 469·9 Feet.

From Mr. J. Prest.

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Made ground	5	0	0			
Turf and soil	0	1	6			
Loam and sandy clay	3	1	6			
Red marl - -	2	2	0			
Rock	0	1	0			
Red marl -	4	0	0			
Blue rock - -	5	0	0			
Grey marl	2	0	0			
Black smut	0	0	6			
Grey marl -	8	0	0			
Red marl - -	9	0	0			
Blue metal	5	0	0			
Grey metal	3	1	6			
Red and grey marl -	6	0	0			
COAL - - - -	0	0	3	54	2	3
Dark marl - -	4	1	6			
Grey marl - - -	1	1	6			
Rock - -	0	1	6			
Metal - - - -	0	0	6			
Rock - - - -	0	1	0			
Blue metal - - -	2	0	0			

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
COAL	0	0	10	64	0	1
Marl	2	0	0			
Strong rock	2	0	0			
Rock binds	0	1	6			
Grey metal	1	1	6			
Black bass	0	0	6			
Grey metal	0	0	3			
Dark bass with balls of ironstone	0	1	0			
HALF YARD STONE	0	1	6			
Black band coal	0	1	0	71	1	4
Grey marl	3	0	0			
COAL	0	1	0	74	2	4
Marl	1	1	6			
Rock	1	1	6			
Blue metal	2	2	0			
Black bass	0	0	3			
Blue metal	1	1	0			
Red marl	1	1	6			
Grey marl	2	0	0			
Blue metal	0	1	0			
"Rocky cinder"	0	2	0			
IRONSTONE	0	0	3			
RED SHAGG COAL	0	2	8			
Grey marl } Thickness not given						
Grey rock }						
Strong grey metal with bands of rock	10	0	0			
Dark metal	3	0	10			
Hard rock	0	1	0			
Dark metal	1	1	6			
Black bass	3	0	0			
Grey metal with rock binds	2	2	9			
GUTTER STONE	0	2	0			
Black bass	0	0	3			
RED MINE COAL	0	2	2	114	2	6
Marl	1	1	10			
Red marl	6	0	0			
Fireclay	0	2	0			
Dark metal	1	1	0			
Red marl	2	1	6			
Dark shale	1	2	0			
Clunch	1	2	0			
Dark shale with small beds of stone	4	2	6			
COAL	0	2	0	135	2	4
Fireclay	1	2	0			
Dark shale	2	1	0			
Bed of stone	0	0	6			
Dark shale with small beds of coal	2	1	0			
COAL	0	1	6	142	2	4
Fireclay	1	1	0			
Strong rock binds	2	0	0			
Strong beds of rock	2	0	0			
Dark shale	2	1	0			
Rock binds	2	1	0			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Grey metal	2	1	0			
Rock binds	1	1	6			
Dark metal	0	2	6			
Strong bands of rock	2	1	6			
Dark metal	10	0	0			
Grey metal	6	2	6			
Dark shale	0	1	6			
Grey metal with beds of stone	10	1	4			
Rock	2	2	2			
Black bass	0	2	0			
BASSEY MINE STONE	0	1	6			
COAL	0	2	2	192	1	0
Fireclay	4	0	0			
Dark metal	1	1	6			
Smut and coal	0	1	6			
Clunch	2	1	6			
Strong grey metal	4	1	6			
Grey metal with small balls of stone	5	0	0			
Bass	0	1	0			
PEACOCK COAL	1	0	6			
Fireclay	2	2	6			
Grey metal	9	1	6			
Dark metal	4	2	6			
Rock binds	4	1	8			
Bass	0	1	6			
SPENCROFT COAL	1	1	0			
Dark marl	1	2	0			
COAL	0	1	6			
Fireclay	2	0	6			
Grey metal	8	0	6			
Dark shale	2	2	0			
Grey metal with bands of stone	3	0	0			
Black bass	1	0	0			
GUBBIN STONE	2	0	0			
Dark shale with bands of stone	1	2	6			
Hard rock	1	0	0			
Rocky binds	2	2	0			
Dark marl	4	1	6			
GREAT ROW COAL	3	0	6			
Dark marl	0	2	6			
Rock binds	1	0	0			

SECTION No. 17.
ROWHURST PIT, SHELTON.
O.D. 460·8 Feet.
From Mr. J. Prest.

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Made ground and clay	14	1	0			
Marl	10	2	6			
Rock	3	0	8			
Binds	3	2	4			

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
Marl	6	2	0			
Rock	0	2	0			
Binds	2	2	0			
COAL	1	0	0	43	6	0
Marl	13	2	0			
Rock	0	2	6			
Marl	14	2	0			
Bass	1	2	0			
BASSEY MINE STONE	0	2	10			
BASSEY MINE COAL	1	0	6	76	4	0
Marl	6	2	0			
COAL	0	2	3			
Marl and bass	11	1	6			
PEACOCK MINE COAL	1	2	6	96	2	7
Binds	4	1	0			
Marl	2	1	0			
Binds	3	0	0			
Rock	0	2	9			
Binds	5	1	3			
SPENCROFT COAL	1	1	0	114	7	0
Black slum shale	1	2	3			
Marl	2	1	0			
Rock binds	8	0	0			
GUBBIN STONE and bass	1	2	0	127	2	0
Blue binds	4	0	0			
Rock	3	2	0			
Rock binds	4	0	0			
Marl	1	2	0			
GREAT ROW COAL	2	1	0	143	2	10
Marl	20	2	0			
Bass	1	1	6			
CANNEL ROW COAL	1	1	6	167	1	10
Stews	1	0	0			
Rock	5	0	0			
Soft blue metal	3	0	0			
Marl	5	0	0			
Strong grey metal	6	0	0			
Rock	0	2	0			
Bass	6	2	0			
Marl	4	0	0			
Bass	5	0	0			
IRONSTONE, "PENNYSTONE," and bass	0	2	6	202	2	4
Marl	3	0	0			
DEEP MINE STONE and bass	3	2	6	208	1	10
COAL	1	0	6			
Marl	16	2	6			
CHALKY bass and stone	1	2	6			
CHALKY COAL	0	1	0	228	2	4
Marl	4	0	0			
Rock binds	9	0	5			
Strong grey metal	5	0	6			
Bass	5	0	6			
Rock	3	0	6			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft	In.	Yd.	Ft.	In.
Rock binds	6	0	6			
BUNGILOW COAL	1	1	6	265	3	0
Rock binds	3	2	0			
Marl	4	0	0			
Rock	13	1	6			
Marl	12	0	0			
COAL	0	1	0	298	1	9
Marl	10	1	0			
Bass	2	0	0			
Marl	11	1	0			
Bass	3	0	0			
Marl	4	0	0			
COAL	0	1	6			
Rock binds	6	0	0			
Marl	8	1	0			
WINGHAY COAL	2	1	0	346	1	3
Marl	4	2	0			
Rock binds	6	0	0			
Strong metals	3	1	6			
Rock binds	6	0	0			
Rock	2	2	6			
Bass	10	2	0			
Black bass	2	2	6			
Dark clod	4	1	6			
Slummy metals	5	1	4			
Bass with ironstone	6	2	6			
COAL	0	1	6	400	7	0
Bass	0	1	2			
COAL	0	1	0			
Marl	1	2	9			
Rock	11	1	6			
Marl	3	0	6			
Metals	8	1	4			
Marl	1	2	1			
Metals	7	1	5			
Bass	3	1	7			
Rock binds	17	2	6			
Bass	5	2	3			
Light bass	1	0	2			
RIDER COAL	1	0	0	464	0	10
Black bass	3	1	0			
Blue metal	0	2	0			
ROWHURST COAL	2	0	6	470	1	4
Marl	4	1	6			
COAL	0	0	8			
Slummy marl	1	1	4			
Bass	2	1	4			
Strong rock binds and bass with beds of "pebbles"	8	2	6			
Rock binds	8	0	0			
Bass with beds of ironstone and coal	3	2	2			
Rock binds	5	0	0			
Black bass and *Burnwood Stone*	1	1	2			
BURNWOOD STONE	0	1	0			
COAL	2	0	0	508	1	0
Marl	0	1	0			
BURNWOOD ROCK	27	0	6	535	2	6

SECTION No. 18.
DEEP PIT, FAR GREEN.
O.D. 580 Feet.
From Mr. J. Prest.

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Clay and made ground	5	2	0			
Dark metal	19	0	0			
Dark metal	6	1	11			
Fireclay	6	1	6			
COAL	6	2	2	38	1	7
Grey metal	3	0	0			
WINGHAY COAL	1	1	6	43	0	1
Black metal	0	2	2			
Grey metal	0	2	1			
Black bass	0	2	6			
Grey metal	5	0	6			
Black metal	0	1	0			
Grey metal	1	1	9			
Black metal	0	2	6			
Grey metal	2	2	8			
Rock metal—dark	1	2	8			
Grey metal	2	1	3			
Black metal	11	1	9			
Grey metal	3	2	7			
Rock metal—dark	2	2	0			
Grey metal	3	2	10			
Rock marl—dark	8	2	0			
BILLEY COAL	0	1	6	91	1	10
Grey metal	4	0	0			
Black metal	5	0	0			
Grey metal	19	0	4			
Black metal	8	2	7			
Grey metal	2	0	0			
Black metal	2	2	6			
COAL	0	1	9	134	0	0
Rock	2	2	8			
Strong grey metal	10	0	0			
COAL	0	2	0	147	1	8
Black metal	16	0	0			
ROWHURST RIDER COAL	1	2	0			
Dark metal	0	1	2			
COAL, Best	2	1	0	167	2	10
Dark metal	0	1	0			
BINGAY COAL	1	0	0			
Grey metal	3	1	6			
Blue marl	2	2	9			
Black marl	1	2	0			
Grey marl	6	1	0			
Grey rock	4	0	0			
COAL	0	1	6			
Black marl	0	2	0	188	0	7
COAL	0	0	6	189	0	1

Character of Strata.	Thickness			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Black dirt	0	2	0			
Grey marl	3	0	0			
Black bass with balls of ironstone	2	0	0			
BURNWOOD COAL	1	2	2	196	1	0
Black dirt	0	0	6			
Fireclay	3	0	0			
Grey marl	4	1	2			
Rock	0	2	6			
Black marl	0	1	8			
Grey marl	2	1	8			
Dark marl	7	0	0			
Black bass	1	2	6			
TWIST CANNEL	0	2	4	217	1	7
TWIST COAL	0	1	8	218	0	3
Grey marl	11	0	0			
Black bass	8	2	0			
COAL	0	1	6	238	0	9
Dark marl	2	2	8			
Grey marl	1	2	4			
Grey marl	2	2	3			
Strong rock	1	0	0			
Black marl	2	0	9			
Grey marl	10	1	9			
Grey marl	7	0	0			
Black bass	3	1	0			
COAL	0	0	3	269	2	9
Grey marl	0	2	9			
Red rock	17	0	0			
Black marl	2	0	0			
Grey rock	10	2	0			
Black metal	2	1	3			
Black bass	2	2	6			
Black metal	1	0	3			
Black metal with ironstone	2	0	0			
COAL	0	1	0	309	0	6
Loamy grey marl	6	1	3			
Grey marl	11	0	0			
Blue marl	7	1	0			
Black bass	1	0	0			
Grey rock	1	0	3			
Grey rock	4	0	0			
Blue metal	7	0	0			
Blue metal	4	2	8			
COAL	0	0	4	352	0	0
Grey metal	6	1	6			
Grey metal	5	0	0			
Black bass	4	1	0			
Black bass	2	2	6			
BIRCHENWOOD OR GRANVILLE COAL { COAL	0	2	3			
BIRCHENWOOD OR GRANVILLE COAL { Dirt	0	1	6			
BIRCHENWOOD OR GRANVILLE COAL { COAL	1	0	3	373	0	0
Grey metal	8	0	0			
Grey metal	5	1	0			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Black bass	2	1	0			
Blue metal	6	0	0			
Black bass	0	2	6			
MOSS COAL	1	0	10	396	2	4
Loamy metal	3	0	0			
Blue metal	7	1	9			
CANNEL	0	0	9			
COAL	0	2	3	408	1	1
Loamy metal	2	1	8			
Black metal	1	2	4			
Grey metal	9	0	9			
Black bass	1	1	6			
COAL	0	2	3	424	0	7
Dark metal	1	2	6			
Blue metal with ironstone	5	1	1			
Strong grey metal	11	0	0			
Rock	20	1	6			
Black bass	5	2	2			
YARD COAL	1	0	6	469	2	4
Grey metal	4	0	0			
Black bass	0	1	0			
Grey metal	2	0	2			
RAGMAN OR FOUR FEET COAL { TOP COAL	1	0	10			
Parting	0	0	2			
COAL	0	0	6	477	2	0
Dark metal	4	0	6			
COAL	0	2	3			
Dirt	0	0	5			
COAL	0	0	6	482	2	8
Dark grey metal	4	2	2			
Rock and bass	0	0	4			
COAL	0	0	2	487	2	4
Grey metal	1	0	0			
Grey rock	12	2	0			
Grey metal	1	0	6			
Black bass	1	1	6	504	0	4
ROUGH SEVEN FEET COAL { COAL	0	1	10½			
Dirt pricking	0	0	4½			
COAL	0	2	3	505	1	10
Dark grey metal	1	0	0			

SECTION NO. 19.

SNEYD COLLIERY, BURSLEM.

O.D. 573·4 Feet.

From Mr. J. Heath.

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Made ground	7	1	2	7	1	2
Cannel row warrant	1	2	0	9	0	2
Marl with large brick nodules	2	2	2½	11	2	4½
Shaley coal	0	0	3½	11	2	8

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Marl	0	2	3	12	1	11
Rock binds	2	0	7½	14	2	6½
Marl	0	1	10	15	1	4½
IRONSTONE	0	0	1½	15	1	6
Marl	0	2	1	15	2	7
Pricking dirt	0	0	3	15	2	10
Rock binds	2	0	6	18	0	4
Marl	0	1	0	18	1	4
Marl	0	1	5	18	2	9
Bass	0	0	4	19	0	1
IRONSTONE	0	0	3	19	0	4
Marl with ironstone nodules	6	0	4	25	1	8
Bass	0	0	6	25	2	2
IRONSTONE	0	0	5½	25	2	7½
Black shale	0	1	2½	26	0	10
Marl	0	1	4	26	2	2
Black shale	0	0	10	27	0	0
Pricking dirt	0	0	6	27	0	6
Marl	2	2	4	29	2	10
Marl with grit stone	1	0	0	30	2	10
Rock binds	1	2	2	32	2	0
Shaley marl	0	2	0	33	1	0
Marl	1	1	4	34	2	4
Bass	0	1	6	35	0	10
IRONSTONE	0	0	1	35	0	11
Bass	4	0	3	39	1	3
Bass	0	1	0	39	2	3
IRONSTONE	0	0	2½	39	2	5½
Bass	0	0	11	40	0	4½
Hard black holing dirt	0	0	0½	40	0	5
Oil shale	0	2	6	40	2	11
IRONSTONE	0	0	6	41	0	5
WOOD MINE COAL	0	0	10	41	1	2
Marl	0	2	3	42	0	5
Rock	1	2	0	42	2	5
Marl	0	1	11	44	1	4
Rock	0	1	1	44	2	5
Marl	0	2	2½	45	1	7½
IRONSTONE	0	0	6	45	2	1½
Bass	0	1	8	46	0	9½
Bass with ironstone nodules	0	1	10	46	2	7½
Bass	1	0	8	48	0	3½
CHALKY IRONSTONE	0	2	8	48	2	11½
Rock	0	0	6½	49	0	4
Marl	0	0	3	49	0	7
Bass	0	0	10	49	1	5
IRONSTONE	0	0	5	49	1	10
Bass	0	1	0	49	2	10
IRONSTONE	0	0	4	50	0	2
Bass	0	1	4	50	1	6
IRONSTONE	0	0	2½	50	1	8½
Bass	0	0	5	50	2	1½
IRONSTONE	0	0	3	50	2	4½

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Bass	0	1	1	51	0	5½
CHALKY COAL	1	0	0	52	0	3½
Marl	0	0	4	52	0	7½
Clunch	1	1	4½	53	2	0
Blue shale	1	0	0	54	2	0
Slagg black	0	1	2	55	0	2
Marl	0	0	4	55	0	6
Clunch	1	2	6	57	0	0
Strong blue shale	6	2	0	63	2	0
Rock	0	1	2	64	0	2
Rock binds	12	0	11	76	1	1
Rock	0	1	0	76	2	1
Rock binds	0	1	1	77	0	2
Blue shale	0	1	0	77	1	2
Bass	0	2	11	78	1	1
IRONSTONE	0	0	2	78	1	3
Bass	0	1	3	78	2	6
IRONSTONE	0	0	2	78	2	8
Bass	0	0	4	79	0	0
COAL	0	0	11	79	0	11
Slagg	0	0	6	79	1	5
Clunch with two beds of ironstone nodules	3	0	0	82	1	5
Clunch with hard brown nodules	1	0	3	83	1	8
NEW MINE COAL	0	0	5½	83	2	1½
Shale	1	0	0½	84	2	2
Strong clunch	2	0	0	86	2	2
Blue shale	1	0	1	87	2	3
Rock binds	0	2	0	88	1	3
IRONSTONE	0	0	7	88	1	10
COAL	0	0	4	88	2	2
Marl	0	2	0	89	1	2
Rock binds	1	1	3	90	2	5
Strong blue shale	0	1	2	91	0	7
Rock binds	0	1	0	91	1	7
Strong blue shale	0	1	0	91	2	7
IRONSTONE	0	0	5	92	0	0
Blue shale	0	1	4	92	1	4
IRONSTONE	0	0	2	92	1	6
Bass	2	2	3	95	0	9
Rock binds	4	2	10	100	0	7
Pricking dirt	0	0	2	100	0	9
Bass	0	1	7	100	2	4
BUNGALOW COAL	1	0	0	101	2	4
Rock and clunch	4	1	0	106	0	4
Strong blue shale	0	1	0	106	1	4
Soft rock binds	0	1	6	106	2	10
Blue shale	1	1	9	108	1	7
Dark marl	0	2	10	109	1	5
Grey marl	0	1	7	110	0	0
Black shaley marl	0	0	8	110	0	8
Hard gritty marl	3	1	6	113	2	2
Grey marl	0	2	8	114	1	10
Bass	5	0	4	119	2	2

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
Rock	0	0	3½	119	2	5½
Blue shale	0	0	2	119	2	7½
IRONSTONE	0	0	3	119	2	10½
Bass	0	1	9½	120	1	8
Rock binds	0	2	3	121	0	11
Blue shale	0	1	7	121	2	6
Bass	0	0	5	121	2	11
COAL	0	0	3	122	0	2
Pricking dirt	0	0	2	122	0	4
Clunch and brown shale	3	0	2	125	0	6
Brown marl	3	0	9	128	1	3
Rock	0	2	1	129	0	4
Hard grey bass with joints	6	1	2	135	1	6
Brown marl	3	1	5	139	0	11
COAL	0	0	7	139	1	6
Black shaley marl	0	1	0	139	2	6
Brown marl	4	1	0	144	0	6
IRONSTONE	0	0	10	144	1	4
Black shaley marl	0	1	0	144	2	4
Brown marl	0	2	6	145	1	10
Very dark marl	0	2	3	146	1	1
Black bass	0	0	6	146	1	7
IRONSTONE	0	0	3	146	1	10
Black bass	0	0	9	146	2	7
IRONSTONE	0	0	4½	146	2	11½
Black bass	0	1	0	147	0	11½
IRONSTONE	0	0	3	147	1	2½
Black shaley bass	0	0	11½	147	2	2
IRONSTONE	0	0	5	147	2	7
Strong bass or very poor ironstone	0	1	4	148	0	11
Hard blue clunch	4	0	5	152	1	4
Black bass	5	0	9	157	2	4
Pricking dirt	0	0	2	157	2	6
Black bass	1	0	11	159	0	5
Black bass	3	1	0	162	1	5
Dark grey bass	2	1	5	164	2	10
Dark grey bass with parting	0	2	6½	165	2	4½
LADY COAL	0	2	0½	166	1	5
Marl	4	0	0	170	1	5
Blue shale with two feet of rock on south side	2	0	5	172	1	10
Marl	4	1	2	177	0	0
WINGHAY COAL	1	1	0	178	1	0
Warrant and bass	1	2	4	180	0	4
Rock binds	9	2	0	189	2	4
Clunch	1	1	9	191	1	1
Strong clunch	2	2	10	194	0	11
Rock binds	6	0	11	200	1	10
WINGHAY IRONSTONE	0	0	6	200	2	4
Strong dark shale	0	2	7	201	1	11
Grit stone	0	0	8	201	2	7
Blue shale	0	1	10	202	1	5
IRONSTONE	0	0	4	202	1	9
Bass	0	1	6	203	0	3

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
IRONSTONE	0	0	4	203	0	7
Black bass with Mussel shells	1	1	9	204	2	4
Black bass	7	1	11	212	1	3
Grey bass	3	0	8	215	1	11
COAL	0	0	2	215	2	1
Dark shale	0	2	6	216	1	7
Clunch	1	0	5	217	2	0
Dark shale	0	2	0	218	1	0
Marl	1	0	0	219	1	0
Clunch	0	2	5	220	0	5
Bass	0	0	2	220	0	7
IRONSTONE	0	0	2	220	0	9
Bass	3	2	5	224	0	2
IRONSTONE	0	0	4	224	0	6
Bass	0	2	5	224	2	11
Black bass	4	0	11	229	0	10
BILLY COAL	0	1	5	229	2	3
Black shale	0	2	4	230	1	7
Black binds	1	0	9	231	2	4
Rock binds	3	2	0	235	1	4
Black bass	0	1	0	235	2	4
Marl	1	0	0	236	2	4
Bass	3	1	6	240	0	10
Blue shale	0	2	3	241	0	1
Blue shale and bind	6	0	3	247	0	4
Bass	7	1	6	254	1	10
IRONSTONE	0	0	2	254	2	0
COAL	0	1	4	255	0	4
Blue shale	3	2	0	258	2	4
Binds	3	2	6	262	1	10
Marl	0	2	0	263	0	10
COAL	0	0	6	263	1	4
Rock bind	6	2	3	270	0	7
Grey bass	5	0	11	275	1	6
COAL	0	1	1	275	2	7
Marl	0	0	4	275	2	11
COAL	0	0	3½	276	0	2½
Clunch	3	0	0	279	0	2½
Strong blue shale	4	0	5	283	0	7½
Rock	0	1	8½	283	2	4
Strong blue shale	1	1	6	285	0	10
Dark grey bass	5	0	3	290	1	1
Black bass	1	0	1	291	1	2
Blue shale	3	0	2	294	1	4
RIDER COAL	1	0	4	295	1	8
Dirt	0	2	3	296	0	11
Working Coal	1	1	7	297	2	6
ROWHURST COAL { Dirt	0	2	4	298	1	10
ROWHURST COAL { Ironstone	0	0	4	298	2	2
ROWHURST COAL { Dirt	0	1	10	299	1	0
ROWHURST COAL { COAL	0	2	4	300	0	4
Clunch with gritty nodules	11	0	0	311	0	4
Bass with ironstone nodules	1	1	0	312	1	4

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Rock with strong blue shale	10	1	0	322	2	4
Blue shale	8	1	0	331	0	4
Black bass	1	2	10	333	0	2
Coal and shale	1	2	8	334	2	10
Shale	2	0	3	337	0	1
Clunch	2	1	1	339	1	2
IRONSTONE	0	0	4	339	1	6
Bass	3	1	4	342	2	10
IRONSTONE	0	1	0	343	0	10
COAL	0	2	5	344	0	3
Slagg	0	0	7	344	0	10
COAL	0	1	0	344	1	10
Slagg	0	0	3	344	2	1
COAL	0	1	1	345	0	2
Slagg	0	0	6	345	0	8
Continued in Shaft No. 2						
Pricking dirt	0	0	8	345	1	4
Shale	1	0	6	346	1	10
Clunch	7	1	6	354	0	4
Black bass	1	0	4	355	0	8
Pricking	0	0	1	355	0	9
CANNEL	0	0	2½	355	0	11½
TWIST COAL	0	2	0½	356	0	0
Dark marl	1	0	4	357	0	4
Blue shale	2	2	6	359	2	10
Rock	6	2	0	366	1	10
Rock binds	1	1	4	368	0	2
Light grey shale	7	0	0	375	0	2
Grey shale	9	0	6	384	0	8
COAL	0	0	6	384	1	2
Rock mixed with strong clod	3	0	4	387	1	6
Clunch	1	0	6	388	2	0
Ironstone	0	0	6	388	2	6
Strong grey clunch	2	1	10	391	1	4
Grey bass	1	0	6	392	1	10
Black bass	1	0	9	393	2	7
Grey clunch	3	0	0	396	2	7
Black bass	1	0	2	397	2	9
COAL	0	0	11	398	0	8
Grey marl	1	0	10	399	1	6
Grey shale	16	0	2	415	1	8
Rock binds	10	1	6	426	0	2
Black shaley marl	1	2	4	427	2	6
Blue bass	0	2	0	428	1	6
Strong clod	1	2	4	430	0	10
Rock binds	3	1	8	433	2	6
Unstratified rock, marl and black bass	2	1	2	436	0	8
Black bass	2	1	0	438	1	8
Black shaley marl, stratified	3	1	5	442	0	1
Black bass	1	0	6	443	0	7
Black metal with small bands of ironstone	0	2	0	443	2	7
Rock binds	2	1	7	446	1	2
Dark bass	7	2	0	454	0	2

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Dark bass	6	1	9	460	1	11
Bass with three bands of light ironstone	0	2	0	461	0	11
COAL	0	1	0	461	1	11
Grey marl	1	1	3	463	0	2
Strong grey clunch	1	0	6	464	0	8
Black and grey marl	3	0	6	469	1	2
Strong blue binds	3	1	0	472	2	2
Rock binds	4	2	6	477	1	8
Blue binds	3	1	3	480	2	11
Grey bass	2	2	9	483	2	8
Strong grey bass	1	1	4	485	1	0
Loose shaley bass	0	1	10	487	2	10
Black bass	1	2	0	487	1	10
Strong grey shale	7	1	2	495	0	0
COAL	0	0	2	495	C	2
Strong dark clunch	6	1	6	501	1	8
Irregular black bass	6	1	0	507	2	8
Binds and clunch in rolls	3	2	4	511	2	0
Grey bass	2	0	10	513	2	10
Strong grey marl	0	2	0	514	1	10
Cannel bass	0	1	2	515	0	0
IRONSTONE	0	0	6	515	0	6
COAL	0	1	4	515	1	10
Shaley marl	2	0	2	517	2	0
Cannel bass	0	1	0	518	0	0
COAL	0	1	8	518	1	8
Bassey cannel	0	1	7	519	0	3
Fireclay	1	2	2	520	2	5
Strong clunch	4	0	0	524	2	5
Grey bass	2	1	5	527	0	10
Strong clunch, like rock	3	1	8	530	2	6
Grey binds	10	1	0	541	0	6
Strong grey binds	3	0	5	544	0	11
Grey bass	0	2	8	545	0	7
Soft jointy grey bass	4	1	5	549	2	0
Black bass	0	0	10	549	2	10
MOSSFIELD COAL	1	1	10	551	1	8
Strong close black binds	2	1	0	553	2	8
Dark grey bass	8	0	6	562	0	2
CANNEL	1	0	10	563	1	0
Strong grey clunch	1	2	0	565	0	0
Dark bass	0	2	6	565	2	6
Dark clunch	2	2	9	569	2	3
Grey metal—fault or slip of 4″	4	2	0	574	1	3
Grey metal	0	2	7	575	0	10
Black bass	2	2	6	578	0	4
Slaggy cannel	0	0	9	578	1	1
COAL	0	0	7	578	1	8
Slag	0	0	4	578	2	0
COAL	0	0	8½	578	2	8½
Rocky clunch	0	0	10	579	0	6½
Fireclay	0	0	5	579	0	11½
Black slag	1	2	6	581	0	5½

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Blue metal	2	0	0	583	0	5½
Blue shale	1	0	6½	584	1	0
Strong clunch	3	2	0	587	0	0
Rock binds in beds	4	2	8	591	2	8
Blue binds	4	2	8	596	2	4
Dark bass	2	1	0	599	0	4
YARD COAL						

SECTION No. 20.

JUBILEE QUEEN PITS, CLANWAY COLLIERY, TUNSTALL.

O.D. 632 Feet.

From Mr. W. Clive.

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft	In.
Curb	0	0	4			
Soil	0	1	4			
HOO CANNEL	0	1	8	1	0	4
Rocky clay	0	1	0			
Marl	0	1	10			
Sandstone rock	1	0	9			
Rocky beds	2	2	8			
Fine marl	6	2	0			
Sandstone block	0	1	8			
Fine marl	2	0	11			
Rock	0	1	1			
Fine marl	1	1	4			
Grey marl	8	0	10			
BLACK BAND	2	2	0			
BASSEY MINE COAL (gob)	1	0	0	29	1	5
Warrant	1	0	0			
COAL	0	2	3	31	0	8
Marl and rock bands	5	0	9			
Fireclay	1	2	8			
PEACOCK COAL	1	2	4	40	0	5
Blue marl	2	1	10			
Marl	6	1	11			
Blue marl	1	0	0			
Marl and rock bands	5	2	0			
Black shale	1	0	4			
Black marl	1	0	0			
Marl and rock bands	2	0	0			
Marl and rock bands	3	0	0			
Dark clod	1	0	4			
SPENCROFT COAL	1	0	4	65	1	2
Black shale, faulty	0	1	2			
COAL	0	2	2	66	1	6
Fireclay	1	1	4			
Dark shale	1	0	2			
Fireclay and ironstone balls	1	0	4			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Fireclay and ironstone bands	9	1	4			
Rock	0	1	2			
Rock bands	0	1	11			
Hard grey rock	0	2	5			
Rock bands	0	1	6			
Rock	0	2	0			
Warrant and strong bands	9	0	0			
Blue metal	0	2	7			
Blue metal	1	1	3			
GUBBIN IRONSTONE	3	0	4			
COAL	1	0	10	99	0	8
Black cannel and bass	1	0	7			
GREAT ROW COAL	1	2	0	102	0	3
Warrant marl	1	0	11			
Fireclay	1	0	0			
Dark metal and stone bands	2	0	3			
Black bass	0	1	9			
Strong grey metal	2	2	6			
Black bass	1	0	3			
HALF YARD COAL	0	2	0	111	1	11
CANNEL ROW COAL	1	0	2			
Dark shale	0	2	11			
Strong grey metal	2	1	8			
Blue metal and rock bands	6	2	0			
Grey metal and rock bands	2	0	0			
Blue metal	2	0	1			
Blue metal	1	1	4			
Black shale	1	1	1			
Black metal and bands of ironstone	6	0	0			
Measures	27	0	9			
CHALKY STONE	0	0	8	163	0	7
Black bass	0	0	3			
CHALKY STONE	0	0	9	163	1	7
White marl	0	1	4			
Bass	0	2	0			
Stone band	1	0	10			
Black bass	1	0	3			
CHALKY COAL	1	0	0	168	0	0

SECTION NO. 21.

BASSEY MINE PIT, GRANGE COLLIERY, COBRIDGE.

O.D. 450 Feet (Approx.).

From Mr. J. H. Cole.

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Made ground	5	2	0			
Stiff marl	1	1	6			
Sand and marl	4	0	0			
Wash and balls of stone	1	0	0			
Grey marl	7	0	2			

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
Red marl	4	2	0			
Grey metal	4	1	6			
Clunch	2	2	0			
Coal	0	0	6			
Red metal	3	2	2			
Strong blue metal	3	2	0			
Grey and blue metal	2	1	8			
Grey and red metal	1	2	5			
Clunch	2	1	0			
Grey metal	2	1	6			
Strong blue metal	4	0	0			
Blue and red metal	3	0	0			
Clunch	3	0	0			
Red and grey metal	4	1	10			
Clunch	0	1	9			
Strong grey rock	1	0	6			
Strong grey metal	1	2	6			
Grey marl	5	1	0			
Grey metal	2	0	0			
Rock binds	1	2	0			
Clunch	1	0	0			
Coal 1 ft. Clunch 3 ft.	1	1	0			
Grey rock	5	1	6			
Strong dark metal	1	0	0			
Bass	0	1	0			
Fireclay	4	2	4			
Coal	0	1	0			
Clunch	0	2	10			
Rock binds	1	2	0			
Grey metal	3	1	5			
Grey and red marl	1	2	10			
Fireclay	1	2	6			
Red Shagg Ironstone	0	2	0	99	2	5
Fireclay	14	0	0			
Grey metal	1	0	0	114	2	5
Dark shale	3	1	0			
Clunch	2	0	0			
Grey metal, 3 ft.; rock binds, 1 ft. 8 in.	1	1	8			
Grey metal, 4 ft. 4 in.; black bass, 5 in.	1	1	9			
Red Mine Ironstone	1	0	0	124	0	10
Red Mine Coal	0	2	3			
Grey and red marl	4	0	9			
Grey metal	1	1	5			
Red marl	2	0	7			
Grey metal	6	1	7			
Slagg, 1 ft. 2 in.; coal 2 ft.	1	0	2			
Fireclay	1	0	8			
Coal	0	2	11			
Strong clunch	1	2	9			
Slagg and coal	1	0	1			
Clunch	6	0	3			
Dark clunch	2	1	0			
Black bass	0	1	0			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Grey clunch	3	0	1			
Slagg and coal	0	1	2			
Grey rock	4	1	8			
Rock binds	4	0	9			
Black bass, 5 in.; stone, 6 in.; coal, 1 ft. 1 in.	0	2	0			
Clunch	5	0	4			
Grey rock and binds	4	0	0			
COAL (HOO CANNEL) 1 ft. 7 in.; black bass, 2 ft. 10 in.	1	1	5	177	2	8
Stone, 4 in.; grey marl, 1 ft.	0	1	4			
Grey rock	6	2	9			
Dark metal	1	1	0			
Grey metal	1	0	0			
Dark metal	1	2	6			
Shale	0	0	8			
Grey rock	2	2	6			
Rock binds	1	1	0			
Dark metal	2	1	6			
Stone bands	0	2	3			
Clunch	1	0	10			
Dark metal	1	2	6			
Strong clunch	1	1	6			
Black bass and stone bands	1	2	0			
BASSEY MINE { Ironstone 0 1 6				203	1	0
Coal 0 1 3						
Ironstone 0 4 10						
Coal 0 0 5 }	2	2	0	206	0	0
Clunch	4	2	6			
COAL	0	1	10			
Strong clunch	3	0	9			
Grey rock	0	1	0			
Clunch	1	1	10			
Stone, 6 in.; strong clunch, 1 ft. 9 in.; dark shale, 3 in.	0	2	6			
Rock binds, 1 ft. 3 in.; bass, 3 in.; rock binds, 1 ft.	0	2	6			
Grey rock	5	0	0			
Grey metal	1	1	0			
Marl	3	1	10			
PEACOCK COAL	1	2	11	230	0	8
Clunch	3	1	9	233	2	5

SECTION NO. 22.
NEW PIT, FORD GREEN.
O.D. 492·1 Feet.
From Mr. J. H. Cole.

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Soil and clay	6	1	0			
SEVEN FEET COAL	0	3	9			
Rock, 27 ft.; holing dirt, 9 in.	9	0	9			
Metal	2	2	6			

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
Black bass	0	1	6			
COAL	0	0	9			
Strong marl	0	2	0			
Rock	3	0	0			
Metal	7	0	0			
COAL, black bass, 9 in.	0	1	0			
Rock binds	3	1	0			
Bass	13	1	0			
Metal	2	0	0			
BELLRINGER COAL	0	3	3			
Clunch	1	1	0			
Strong metal	7	2	0			
Rock	36	2	0			
Metal	7	1	6			
TEN FEET COAL	1	1	6			
Holing dirt, 9 in. coal	0	1	0			
Clunch, 4 ft. 6 in. coal	0	1	6			
Warrant	1	1	10			
Metal	19	2	6			
Strong rock	3	0	6			
Metal	11	2	0			
BOWLING ALLEY COAL	0	3	2			
Fireclay	0	2	0			
Clunch	5	0	0			
Metal	25	0	0			
HOLLY LANE COAL	0	3	10			
Warrant	1	2	6			
COAL	0	1	8			
Warrant	1	1	7			
Metal	4	2	0			
COAL	0	1	0			
Metal	23	1	8			
HARD MINE COAL	1	1	0			
Marl	0	2	6			
Metal	9	0	6			
COAL	0	1	4			
Shale and Bass	8	1	6			
COAL	0	1	6	229	0	7
Warrant, 2 ft. strong rock	3	1	0			
Shale	0	1	6			
Rock	3	0	0			
Metal	42	1	0			
IRONSTONE	0	0	5			
Bass, 1 ft., coal, 1 ft. 4 in.;	0	2	4			
Warrant, 3 ft. 3 in.; metal, 3 ft. 9 in.	2	1	0			
COAL	0	0	6			
Metal	9	0	0			
Rock	26	1	9			
FROGGERY COAL { Coal	0	3	4			
FROGGERY COAL { Bass	0	0	5			
FROGGERY COAL { Coal	0	0	8			
Fireclay	0	6	0			
Bass marl and metal (all mixed)	4	2	6			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In
Coal 6 in.; bass, 4 in.; *coal*, 6 in.	0	1	4			
Fireclay	1	0	0			
Rock	1	1	8			
Metal	13	1	0			
COAL	0	1	0			
Shale	7	2	6			
Rock	3	2	0			
Rock binds (with metal partings)	7	0	0			
Metal	5	2	6			
COCKSHEAD COAL	2	1	4			
Warrant	1	2	0			
Shale	1	2	0			
Strong metal	5	0	0	377	1	4

SECTION No. 23.

INSTITUTE SINKING PIT, WHITFIELD COLLIERY.

O.D. 588 Feet.

From Mr. E. B. Wain.

Inclination of Strata, 15 Degrees.

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Filled up dirt	2	0	0			
Yellow Clay	2	0	0			
RAGMAN COAL	1	0	0	5	0	0
Fireclay	2	0	0			
Grey Rock	3	1	6			
Grey soapy metal	2	1	0			
Grey rock	0	1	3			
Grey soapy metal	8	0	0			
OLD WHITFIELD COAL (GOAF)	1	0	6			
Warrant	0	2	0			
Soapy metals with ironstone nodules	7	0	0			
COAL	0	1	4	30	1	7
Warrant	1	0	0			
Grey soapy metal	6	0	4			
COAL	0	1	4			
Warrant	0	1	6			
Grey rock	2	0	3	40	2	0
Grey soapy metal	2	1	0			
Grey rock	0	2	9			
Grey soapy metal, with ironstone bands	3	0	9			
COAL	0	1	0	47	0	6
Grey rock bands	5	2	0			
Dark blue metal	3	1	1	56	0	7
Grey rock	3	1	6			
Stony grey metal	5	2	0			
Dark soapy metal	4	0	0			
Light soapy metal	3	0	0			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
BELLRINGER COAL	1	0	5	73	1	6
Dark hard rock	0	0	4			
COAL	0	0	6			
Light rock binds	7	0	0			
Grey strong "Ten feet rock"	39	0	0			
Dark soapy metal	1	0	4			
TEN FEET TOP COAL	2	0	0			
,, ,, STOOLS	0	1	6			
,, BOTTOM STOOLS	0	1	8	124	0	10
Soft grey warrant	1	1	2			
Grey rock binds	0	2	0			
Strong grey rock	1	0	0			
Grey rock binds	7	2	0			
Black metal	2	0	0			
Strong grey metal	11	0	2			
BOWLING ALLEY COAL	1	0	3	149	0	5
Top grey marly warrant	1	2	0			
Black bass, full of ironstone nodules	8	0	5			
Strong grey Holly Lane rock	17	0	0			
HOLLY LANE COAL	1	0	2	177	0	0
Grey marly warrant	2	1	8			
LITTLE COAL	0	1	4			
Grey soapy metal	7	1	6			
Grey rock	6	0	0			
Strong grey metal with ironstone nodules	13	1	6			
HARD MINE COAL	1	1	4	208	1	4
Grey marly soapy metal, ironstone nodules	8	0	0			
Dark soapy metal	6	0	0			
Very strong grey metal, last 10 yards very strong	26	1	6			
Grey rock binds very strong, with ironstone nodules	24	1	8			
Dark shaly bass, with ironstone nodules	18	0	0			
SMALL BRIGHT COAL	0	1	0			
Grey metal	1	1	0			
Grey metal and black bass	1	1	0			
Grey metal	1	1	0			
LITTLE COAL	0	0	6			
Dark metal and bass	8	1	0			
Bands of ironstone	0	0	6			
Back bass	1	0	0			
Ironstone bands	0	0	4			
Dark metal	0	1	6			
IRONSTONE COAL	0	2	0	306	2	4
Soft fireclay	0	1	6			
Strong grey metal, ironstone bands	21	0	0			
Grey rock	0	2	0			
"Granite" rock	1	0	0			
Grey rock	2	1	0			
Grey sandy metal	14	0	0			
BANBURY COAL, TOPS	1	0	10			
Strong black bat	0	0	4			
COAL	0	1	1			
Black metal	0	0	6			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
BOTTOM COAL	0	1	10	348	2	5
Light marly warrant	0	2	5			
Strong grey stony metal	4	0	0			
Grey rock	4	0	0			
Dark strong metal	10	0	0			
LITTLE COAL	0	0	9			
Soft grey warrant	6	0	0			
Mild grey warrant	16	0	5			
Strong grey metal	7	1	0			
Grey rock	0	2	0			
Very strong grey metal	8	0	0			
COCKSHEAD COAL	2	1	6	408	1	6
Bright black	20	0	4			
Black bass, full of ironstone nodules	20	1	2			
Grey soap metals	1	1	2			
LITTLE COAL	0	1	10	431	0	0
Grey metal	2	0	0	433	0	0

SECTION No. 24.

MIDDLE PIT, CHATTERLEY AND WHITFIELD COLLIERY.

O.D. 588 Feet.

From Mr. E. B. Wain.

Character of Strata.	Thickness.		
	Yd.	Ft.	In.
From surface to old Ten Feet landing	148	1	0
Old landing to Bowling Alley	25	1	6
BOWLING ALLEY COAL	1	0	2
Fireclay	0	1	3
Warrant	1	2	0
Close metal without partings	4	0	0
Rock binds mixed with metal	5	2	6
Grey rock	13	1	0
HOLLY LANE COAL	1	0	0
Fireclay	0	0	3
Strong metal with ironstone pebbles	14	0	0
Metal	2	0	0
Rock	2	0	0
Metal	1	2	3
Mild rock	2	0	0
Soft metal with ironstone bands	10	0	0
HARD MINE COAL	1	1	4

SECTION No. 25.
BRADLEY GREEN COLLIERY (corrected for dip).*
From Mr. Bradbury.

Character of Strata	Thickness.	
	Ft.	In.
MAGPIE COAL	5	0
Measures	43	0
HOLLY LANE COAL	4	0
Measures	158	0
BOWLING ALLEY COAL	6	0
Measures, with irregular TWO FEET COAL	70	0
STINKING COAL in three seams	3	0
Measures	100	0
IRONSTONE MINE COAL	2	3
Measures	185	0
FROGGERY COAL (1 ft. 6 in. bad at the bottom)	5	0
Measures	145	0
COCKSHEAD COAL	9	0
Measures, with LIMEKILN or SUDDEN COAL	220	0
BULLHURST COAL	6	0
Measures	53	0
WINPENNY COAL	3	0
Measures	170	0
BRICK-KILN ROW COAL	1	6
Measures	200	0
SILVER MINE COAL	3	0

SECTION No. 26.
TOWER HILL COLLIERY (corrected for dip).*
O.D. 725 Feet (Approx).
From Messrs. Williamson.

Character of Strata.	Thickness.	
	Ft.	In.
ROUGH SEVEN FEET COAL	6	0
Measures, with little COAL	90	0
STONY EIGHT FEET COAL 6 ft. to	7	0
Measures	60	0
TEN FEET COAL	5	6
Measures	189	0
TOP TWO ROW, or MAGPIE COAL	5	0
Measures	5	0
UNDER TWO ROW, or HOLLYLANE COAL	3	0
Measures	100	0
BOWLING ALLEY COAL	5	0
Measures	160	0
SEVEN FEET BANBURY or FROGGERY COAL	2	3
Measures	140	0
EIGHT FEET BANBURY, or COCKSHEAD	7	6
Measures	185	0

* *Mem. Geol. Survey.*—Geology of the Country around Stockport, Macclesfield, Congleton, and Leek, p. 31.

Character of Strata.		Thickness.	
		Ft.	In.
BULLHURST COAL	2 ft. to	6	0
Measures		70	0
WINPENNY COAL		3	0

SECTION No. 27.

NEW ENGINE PIT, BIDDULPH COLLIERY.

From Mr. J. H. Cole.

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Soil	0	2	3	0	2	3
Clay	4	0	0			
Sandstone	3	0	6½			
Metal	2	2	0			
TEN FEET COAL	2	0	5	12	2	2½
Warrant	1	0	5			
BILLEY COAL	0	1	6½			
Warrant	2	2	8			
White marl	2	1	6			
Red rock	33	1	4			
Red metal	11	1	3			
White metal	8	1	6			
MAGPIE COAL	1	1	0	74	1	5
Warrant	12	0	0			
HOLLY LANE COAL	1	1	0	87	2	5
Warrant	1	2	0			
BILLEY COAL	0	1	0			
Warrant	18	1	10			
Grey rock	17	0	9			
Hard Mine roof clunch	1	2	0			
HARD MINE COAL	1	1	9	128	2	9
Warrant	6	1	1			
MUCK ROW COAL { Coal	0	0	9	135	2	5
MUCK ROW COAL { Hussle	0	2	7	136	2	0
MUCK ROW COAL { Coal	0	0	1	137	0	0
Strong metal	12	1	3			
Shale	0	2	9			
Metal	2	2	0			
COAL	0	1	0	153	1	0
Dirt	0	0	3			
Dirt	0	0	3			
COAL	0	0	9	153	2	0
Warrant	1	0	0			
Rock	5	1	8			
Strong metal with iron bands	2	2	9			
Rock	7	1	9			
Strong metal with iron bands	4	0	0			
Black bass	18	2	8			
Shale	0	2	0			
COAL	0	1	2	194	2	0

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In
Black bass	2	0	9			
COAL	0	0	7	197	0	4
Black bass	9	2	9			
Ironstone	0	0	6			
Black bass	0	2	7			
IRONSTONE COAL	0	2	2	208	2	4
Warrant	0	2	0			
White rock	1	1	0			
White metal	2	1	10			
Marl	1	0	0			
Clunch	1	2	3	216	0	5

SECTION No. 28.

ROOKERY PITS, JAMAGE COLLIERY.

O.D. 550 Feet (approx.).

From Mr. R. R. Makepeace.

Character of Strata.	Thickness		Depth.	
	Ft.	In.	Ft.	In.
Made ground	22	0		
Soil and clay	6	0		
Clay (below culvert for pump)	9	0		
Marl	45	0		
Bass	2	0		
*STONY EIGHT FEET COAL	2	0	86	0
Clunch	10	0		
Metal and rock binds	18	0		
Rock	41	0		
Bass	8	0		
TEN FEET COAL	8	0	171	0
Fireclay	15	0		
Rock	2	0		
Clunch	11	0		
COAL	0	6	199	6
Metals and rock binds	46	0		
Shell-bed (many crushed shells of *Carbonicola*)	0	8		
Bass	4	4		
TOP TWO ROW COAL	3	0	253	6
Fireclay	5	0		
Rock	4	0		
Rock binds	2	0		
Bass	3	0		
BOTTOM TWO ROW COAL	4	0	271	6
Metals	24	0		
COAL	2	0	297	6
Metals	16	0		
COAL	0	6	314	0

* The part of the section above the Ten Feet Rock was not personally measured by Mr. Makepeace, by whom the section was drawn up, but is from information obtained from the workmen.

Character of Strata.	Thickness Ft.	In.	Depth. Ft.	In.
Fireclay	4	0		
Metals	12	0		
COAL	1	6	331	6
Fireclay	2	0		
COAL	0	6	334	0
Metals and rock binds	135	0		
Rock	39	0		
Metals	67	0		
Seven Feet Bambury Rock	60	0		
SEVEN FEET BAMBURY COAL	7	0	642	0
Fireclay	30	0		
Grey Metal	9	6		
Rock	14	0		
Brown rock	1	6		
Ironstone	0	3		
COAL	0	4	697	7
Black Bass	3	0		
Rock	20	0		
Blue metal	20	0		
Black bass	6	0		
Blue metal	23	0		
Black bass	1	6		
EIGHT FEET BAMBURY COAL	8	0	779	1
Grey metal	9	0	788	1

SECTION No. 29.

DIGLAKE SHAFTS, AUDLEY COLLIERY.*

O.D. 515 Feet (approx.).

From Mr. F. Rigby.

(Section begins five yards below top of shaft.)

No. 1 SHAFT NORTH.

Character of Strata.	Thickness Ft.	In.	Depth. Ft.	In.
Clay	–	–	15	0
Ten Feet Rock	76	0	91	0
Black shale	9	0		
TEN FEET COAL	10	9	110	9
Grey glum	3	0		
CANNEL	1	0	114	9
Grey bass	21	6		
Black bass	1	6		
Grey bass	1	3		
Two Row Rock	11	6		
Grey bass	14	0		
Black bass with ironstone bands	19	0		
Grey bass	9	0		
LITTLE ROW COAL	4	7	197	1
Grey glum and slag	6	6		

* This section begins in No. 1 Shaft and is continued in No. 2 Shaft.

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
TWO ROW COAL	4	6	208	1
Grey glum	12	6		
COAL	2	4	222	11
Strong rock binds	15	0		
COAL	0	3	238	2
Rock binds	3	6		
Rock	1	6		
Rock binds	6	[illegible]		
Strong metals	9	0		
BOWLING ALLEY COAL	1	6	260	2
Grey glum	20	6		
Strong grey metals with rock balls	162	0		
Strong rocky *leapy* ground	40	6		
Strong glum (*leapy*)	13	6		
Rocky ground (*leapy*)	36	0		
Dark shale	5	0		
COAL	1	6	539	2
Dirt	1	0		
COAL	1	6	541	8
Rock binds	10	0		
Bass	1	6		
COAL	1	6	554	8
Rocky ground (*leapy*)	19	0		
COAL and Shale	8	0	581	8
Strong glum	5	0		
Strong rocky ground (*leapy*; dip varying)	58	0		
COAL	0	6	645	2
Strong metals	13	0		

(CONTINUED IN NO. 2 SHAFT (SOUTH)).

NO. 2 SHAFT.

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Rock (dip regular)	9	0		
Black bass	2	0		
COAL	2	0	671	2
Strong grey metals	17	0		
Strong rocky ground	7	6		
Strong rock	11	0		
Grey metals	26	6		
BULLHURST COAL	15	0	748	2
Warrant	10	0		
Grey metals	22	0		
Total			780	2

SECTION No. 30.

BATH OR HARECASTLE PIT, BIRCHENWOOD COLLIERY.

O.D. 500 Feet (approx.).

From Mr. J. Settle.

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Soil	0	1	0			
Yellow clay	1	2	0			
Blue	1	0	0			
Roach	1	2	0			
Sand	15	0	0			
Stone	0	0	4			
Soft shale	5	0	0			
Bass	0	2	0			
NEW MINE STONE	0	0	5	25	1	9
COAL	0	0	4			
Shale	0	1	6			
COAL	0	0	4			
Dark fireclay	0	2	0			
Light fireclay	1	1	0			
Strong blue metal	15	0	0			
Light grey rock	15	0	0			
Light metal	0	2	6			
Grey rock	4	0	0			
Light blue metal	1	1	0			
Strong grey metal	5	2	0			
Light metal	13	0	0			
Rock with Coal Bands	2	2	0			
Light fireclay	3	0	0			
Rock	2	0	0			
Blue shield bass	30	0	0			
BEE COAL	0	1	9	121	1	2
Fireclay	1	1	0			
Blue shield bass	10	0	0			
Fireclay	1	1	0			
LITTLE COAL	0	0	6	134	0	8
Fireclay	1	2	0			
Rock	10	0	0			
Blue shield bass	10	0	0			
Fireclay	1	2	0			
Blue shield bass	3	1	9			
Band of white rock	0	1	6			
Strong blue shield bass	10	0	0			
Fireclay	1	1	0			
Blue metal	9	1	10			
Soft dirt	0	1	0			
Rock bands and blue metal	8	2	0			
Black bass	2	0	0			
Shield bass (black)	7	1	0			
Soft dirt	1	0	0			
BIRCHENWOOD COAL	1	2	3	203	2	0
Strong dark grey metal,	6	0	0			
LITTLE ROW COAL	0	2	3	210	1	3
Strong warrant	1	1	0			
Total	211	2	3			

SECTION No. 31.
No. 1 SHAFT, TALK O' TH' HILL COLLIERY.
(Average Dip 19 Degrees S. E.).
From Mr. A. M. Henshaw.

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Marl	–	–	–			
Rock	4	2	10			
Blue metal	6	0	4			
Black metal	0	1	3			
COAL	0	1	0			
Black bass	0	1	7			
Warrant	3	1	1			
Blue metal	29	0	5			
Hard rock	8	0	2			
Grey metal	18	2	3			
Blue metal	4	0	11			
Black bass	1	1	2			
ROUGH SEVEN FEET COAL	2	0	7			
Clay band	0	0	1			
BOTTOM COAL	0	1	6			
Warrant	1	0	8			
Grey metal	7	0	0			
Black bass	1	0	0			
White earth	0	0	3			
CANNEL	0	1	3			
Warrant	1	2	6			
Dark metal	6	2	0			
White earth	0	2	0			
STONY EIGHT FEET COAL	1	0	1			
Brown stone	0	0	8			
Warrant	2	0	6			
Rock	36	0	0			
Metal	5	0	0			
TEN FEET COAL	3	0	6			
Grey warrant	2	0	0			
Rock	4	2	0			
Black bass	1	0	0			
CANNEL	0	1	0			
Hard white rock	1	1	0			
Grey linsey rock	2	1	0			
Dark metal	4	0	0			
Black bass	4	1	0			
Blue metal	3	0	0			
LITTLE ROW COAL	0	1	3			
Black bass	0	0	6			
Warrant	0	1	6			
Hard brown rock	0	1	2			
Grey metal	2	0	6			
Hard brown rock	0	2	0			
Grey metal	3	1	0			
COAL and BASS	0	1	0			
TWO ROW COAL	1	0	7			

Character of Strata.	Thickness. Yd. Ft. In.	Depth. Yd. Ft. In.
Warrant	1 2 0	
Black metal	0 1 0	
White rock	2 0 0	
Grey metal	3 1 0	
Warrant	0 0 4	
MUCK COAL	0 2 4	
Black bass	0 0 8	
Warrant	0 1 0	
Hard white rock	3 0 0	
COAL	0 0 4	
Warrant	3 0 8	
Dark blue metal	1 2 0	
COAL	0 1 0	
Warrant	4 2 4	
Grey metal	1 2 3	
Warrant	2 2 9	
Grey metal	4 1 3	
Dark blue metal	12 1 0	
Hard rock	0 0 6	
Blue metal	0 1 6	
Rock bands	0 0 6	
Blue metal	0 1 6	
Rock bands	0 0 6	
Blue metal	1 0 0	
Rock bands	0 0 4	
Dark blue metal	3 2 8	
Dark blue metal with ironstone bands	2 1 6	
Grey metal	2 2 5	
Rock bands	0 0 6	
Blue metal	0 0 10	
Ironstone band	0 0 2	
Dark grey rock	1 1 0	
Ironstone bands	0 0 9	
Blue metal and ironstone bands	0 2 0	
Black bass	0 2 0	
Grey metal	0 1 0	
White sparry rock	3 0 0	
Rock	3 2 0	
Fault (25 yds., downthrow east), metal in fault	1 2 6	
COAL	0 0 10	
Warrant	0 1 6	
COAL	0 1 7	
Black bass	2 1 2	
COAL	0 2 0	
Warrant	2 0 6	
White rock	0 2 0	
Grey metal	1 2 6	
White rock	18 2 1	
SEVEN FEET BAMBURY COAL	2 1 10	
Warrant	7 2 5	
Grey metal and ironstone	3 1 0	
Dark grey rock	4 1 10	
Brown burr	0 0 11	

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Ironstone bands	0	0	2			
KIDNEY COAL	0	0	4			
Black bass	1	0	0			
Brown burr	1	2	0			
Dark soft rock	1	0	0			
Brown burr	1	0	0			
Dark linsey rock	3	0	0			
Light blue metal	7	0	8			
Black bass	2	0	0			
Light blue metal	7	0	0			
Black bass	0	1	0			
EIGHT FEET BAMBURY COAL	2	2	4			
Grey metal	4	1	6			
Blue metal	3	1	0			
Dark shale with ironstone	8	0	6			
Blue metal	1	2	4			
Post and metal with ironstone	6	0	0			
Dark shale and ironstone	4	1	0			
COAL	0	1	10			
Grey shale	1	0	0			
Hard post	0	1	2			
Grey metal with post and ironstone	1	2	0			
Dark metal	0	1	2			
COAL	0	1	6			
Post and metal mixed	2	1	6			
Hard white post	1	1	0			
Grey metal	3	1	9			
Blue metal and ironstone	1	0	0			
Hard dark shale	0	2	3			
Blue metal and ironstone	1	1	0			
COAL	0	2	0			
Metal parting	0	1	3			
COAL	0	1	3			
Blue metal and shaly post	4	1	2			
Very hard stone	0	0	11			
Dark metal shale and ironstone	4	2	1			
Hard post band	0	0	8			
Blue metal	0	2	0			
Hard post	0	2	9			
Blue metal	0	2	9			
Post binds	0	0	8			
Soft blue metal	2	2	0			
Dark shale	1	0	4			
BULLHURST COAL. { COAL	1	0	3			
BULLHURST COAL. { Band	0	0	6			
BULLHURST COAL. { COAL	2	0	9			

SECTION No. 32.
No. 5 SHAFT, TALK O' TH' HILL COLLIERY.
O.D. 595 Feet (approx.).
From Mr. A. M. Henshaw.

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
Soil - -	0	1	3			
Clay -	2	1	3			
Rock	0	1	0			
Rock and marl -	1	0	6			
Ten Feet Rock - -	20	1	4			
Bass in bands -	1	1	0			
Black bass	3	0	0			
COAL -	0	2	0	29	2	4
Stone sheard -	0	0	1			
TEN FEET COAL	2	0	3	31	2	8
Fireclay - -	0	0	1			
BILLY COAL -	0	0	10	32	0	7
Warrant and rock binds -	6	2	3			
Black shale - -	0	1	4			
Metal	1	1	0			
Black bass - -	1	0	0			
Brown rock binds	1	0	6			
Metal -	5	1	3			
Grey rock - -	1	1	4			
COAL - -	0	0	4	49	2	0
Fault -	5	0	0			
Bass - -	0	2	6			
Black shale - -	0	0	4			
Rock -	0	1	2			
Metal -	3	0	0			
Rock binds -	1	0	4			
COAL - - - -	0	0	7	60	0	8
Black bass - - - - -	0	0	·6			
Metal - - -	3	1	6			
Black shale - -	0	0	4			
Ironstone - - - - - - -	0	0	2			
Bass - - - - - -	0	0	4			
COAL - -	0	0	9	64	1	1
Warrant - - - - -	2	1	7			
Grey metal - -	14	0	0			
Strong grey metal	4	0	0			
Rock -	0	0	11			
Rock binds - -	1	2	0			
Grey rock binds -	0	2	6			
Grey metal clod - -	33	0	2			
Fault, metal, rock, and ironstone bands -	6	0	0			
Ironstone - - -	0	0	6			
Metal - -	1	0	0			
Ironstone - -	0	0	3			
Bass -	1	0	0			
Ironstone -	0	0	3			
Metal - - -	3	0	6			
COAL - - - - - - - - -	0	0	10	132	1	6

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Hussle bass	0	1	2			
COAL	0	1	0	133	0	6
Metal	3	0	0			
COAL	0	1	5	136	1	6
Warrant	2	0	6			
Bambury Rock	23	0	0			
SEVEN FEET BAMBURY COAL	2	1	0	162	0	5
Warrant	6	0	0			
Rock	1	1	0			
Light fireclay	1	2	4			
Rock bind	3	2	0			
Ironstone band	0	1	8			
Strong metal	2	0	2			
Black hussle	0	1	6			
Stone bind	0	1	6			
Rock	1	1	0			
Blue metal	5	1	2			
Black bass	6	2	4			
Stone bind	1	1	2			
Grey metal	0	2	10			
Grey rock	0	1	7			
Blue metal	6	2	3			
Metal and ironstone bands	2	1	5			
Hussle	0	1	0			
EIGHT FEET BAMBURY COAL	2	2	9	206	2	4
Eight Feet Bambury Warrant	1	2	3			
				208	1	7

SECTION No. 33.

DIAMOND DRILL BORING, TALK O' TH' HILL COLLIERY.
O.D. 590 Feet (approx.).

From Mr. A. M. Henshaw.

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Surface soil	4	9		
Mud (thickness as altered in MS.)	2	5		
Gravel	10	3		
Sandy clay	2	4		
Sandy clay and gravel	9	3		
Blue shale	7	4		
Blue sandstone	1	0		
Flakey sandstone	18	9		
Grey bind	3	11		
Bind and sandstone	6	2		
Dark sandstone	22	0		
Hard sandstone	18	4		
Sandstone with white bands	16	0		
Sandstone with no bands	12	0		
Bind and sandstone	3	0		
Black shale	17	2		

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Bind and sandstone - - - -	9	10		
Dark shale - - - -	20	6		
BEE COAL -	5	3	190	3
Fireclay - - -	0	3		
Bind and sandstone - -	2	0		
Black shale and fireclay - - - - -	8	0		
Black shale - - - -	18	0		
Sandstone - - - -	9	0		
Shale - -	3	0		
Fireclay - -	0	3		
Bind and stone -	3	9		
Sandstone - -	7	0		
Dark sandstone -	6	7		
Shale -	0	5		
Blue bind - - - -	28	6		
Dark shale - - - - -	2	0		
Fireclay- - -	2	3		
Bind -	0	9		
Shale with ironstone bands -	3	6		
Fireclay with ironstone bands -	6	0		
COAL - - -	0	11	292	5
Fireclay - - -	1	1		
Dark fireclay - -	4	1		
Shale - - -	1	6		
Blue shale - - - -	7	6		
Grey bind - - -	38	0		
Sandstone - - -	2	6		
Grey bind	13	6		
Blue bind	4	0		
Sandstone - -	1	6		
Blue bind - -	9	6		
BIRCHENWOOD COAL - -	4	7	380	2
Bind - - - - -	0	6		
Shale - - - - -	6	6		
Shale, light - - -	0	9		
COAL - - - - - - -	0	9	388	8
Shale - - - - - - - - -	2	6		
Bind - - - -	5	0		
Dark bind - - -	1	0		
Black shale - - - - -	13	6		
Shale - - - - - -	5	0		
COAL - - - - -	2	6	418	2
Fireclay - - - - - - -	5	0		
Blue bind - - - - -	7	0		
Blue sandstone - - - - -	24	6		
Bind with nodules of ironstone - -	15	6		
CANNEL - - - - - -	0	3	470	5
Shale - - - - -	0	9		
COAL - - - - - - - - -	1	7	472	9
Shale - - - - - - - -	1	6		
Fireclay - - - - - -	1	6		
Light fireclay (added subsequently in MS.) - -	2	6		
Blue bind - - - - - - -	48	0		

Character of Strata.	Thickness		Depth.	
	Ft.	In.	Ft.	In.
Blue bind with sandstone	10	0		
Sandstone	28	0		
Blue bind	21	0		
Grey bind	9	6		
Grey shale	32	0		
Sandstone	52	0		
			678	9

SECTION No 34.

LAWTON PIT, LAWTON AND HARECASTLE COLLIERY.

O.D. 395 Feet (approx.).

From Mr. J. MacGowan, sen.

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Clay with sand	4	1	0			
Sand	1	2	0			
Strong clay	5	0	0			
Clay with sand	4	1	6			
"Bowlers" of coal	0	2	0			
Marl or white clay with balls of rock	5	1	0			
Soft fireclay	1	0	6			
Black metal	1	2	6			
COAL	2	0	6	26	2	0
Grey metal with iron balls	1	1	6			
COAL	0	1	6			
Fireclay	0	1	6			
Strong metal with balls	0	2	0			
Soft marl	0	1	0			
Black metal	3	1	6			
Light blue metal	3	1	6			
Marl with iron bands	0	2	0			
BOWLING ALLEY COAL	1	0	0	38	2	6
Marl with ironstone balls	1	2	6			
Rock	3	0	0			
Rock bands	1	2	0			
Grey metal	0	1	0			
Marl or fireclay with coal pipes	3	0	0			
COAL, *faulty*	0	1	0			
Black smutty dirt	0	0	3			
Marl	0	1	6			
Clunk	2	0	3			
Rock	1	0	0			
COAL	0	0	3			
Grey marl	0	1	6	53	0	9
Grey metal	1	0	3			
Rock binds	2	0	0			
Whin or peldon	0	1	0			
Grey metal	0	0	6			
Whin or peldon	0	1	0			
Blue metal	0	1	6			
Grey metal	0	2	0			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Blue metal	1	0	0			
Grey metal	2	0	6			
Marl	2	0	6			
Black bass with bands of ironstone	5	0	0			
Rock binds	4	1	0	73	0	0
White rock	7	1	6			
COAL, *faulty*	0	1	0			
Marl	4	0	0			
Blue metal	4	0	0			
Rock	9	0	0			
Rock binds	2	0	0			
COAL and marl	1	0	0			
Black metal	0	2	0	101	1	6
White rock	3	0	3			
Blue metal	0	0	9			
Grey rock	1	0	0			
Peldon	0	0	3			
Black bass	4	0	0			
COAL	0	0	3			
Cockle-shell bass	1	0	6			
COAL	0	0	9			
Rock bind	2	1	6			
Grey metal	1	2	0	115	1	9
Black bass	1	1	0			
COAL, *faulty*	0	1	0			
Grey metal with bands of peldon	2	0	3			
Black bass	1	0	0			
Marl	2	0	0			
Grey rock	0	2	0			
Blue metal	8	1	6			
Marl or fireclay	0	2	0			
Rock binds	0	2	0			
Marl or fireclay	0	1	0			
Strong grey metal with balls of peldon	2	1	6			
Strong peldon	0	1	6			
Strong rock binds	2	1	6			
Grey rock	0	1	6			
Blue metal	0	2	3			
Rock binds	2	1	6			
Strong rock	1	2	0			
Blue metal	1	0	0			
Rock binds	0	2	0			
Blue metal	0	2	6			
Rock	0	1	6			
Blue metal	1	1	3			
Rock	0	1	0			
COAL	3	0	0	152	0	0
Black warrant	1	1	6			
Strong clunk	2	0	0	155	1	6
Rock bind						

SECTION No. 35.

SLAPPENFIELD PIT, LAWTON AND HARECASTLE COLLIERIES.

O.D. 430 Feet (approx.).

From Mr. J. MacGowan, sen. (Dip 13 degrees.)

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
TWO ROW COAL		—		46	0	0
MUCK COAL		—		51	0	0
BOWLING ALLEY COAL	1	0	2	75	0	0
Warrant	0	1	0			
Dark metal	5	0	10			
COAL	0	1	5	81	0	3
Dark metal	2	2	0			
Black bass	0	0	3			
COAL	0	1	1	84	0	7
Grey warrant	2	2	0			
COAL	0	0	3	86	2	10
Grey warrant	1	0	3			
Strong blue metal	1	2	0			
COAL	0	0	6	89	2	7
Strong blue metal	3	0	0			
Dark grey rock	6	0	0			
Blue metal	6	0	0			
Black bass	12	0	7			
COAL	0	0	9	117	0	11
Very hard grey rock	1	0	9			
Black bass	2	2	0			
COAL	0	2	0	121	2	8
Strong blue metal	2	1	1			
Bambury Rock	27	0	0			
SEVEN FEET BAMBURY COAL	2	2	7	154	0	4
Shaly warrant	0	1	6			
COAL	0	0	3			
Fireclay	3	0	0			
Grey metal	6	1	6			
Strong rock	1	1	6			
Black bass	0	1	6			
Strong rock binds	2	0	0			
Blue metal	1	1	6			
Black bass	3	1	0			
Grey metal	1	2	0			
Grey metal	0	1	6			
Whin or rock	0	1	6			
Grey metal	9	1	3			
EIGHT FEET BAMBURY COAL { COAL	0	1	0			
EIGHT FEET BAMBURY COAL { Shaly binds	0	0	2			
EIGHT FEET BAMBURY COAL { COAL	2	2	0	188	0	6
Post and metal mixed	4	1	6			
Ironstone	0	0	10			
Post and metal mixed with ironstone	4	0	0			
Dark shale with ironstone	7	0	8			
Blue metal	1	2	4			
Post and metal mixed with ironstone	6	0	0			
Dark shale and ironstone	4	1	0			

Character of Strata.	Thickness. Yd. Ft. In.	Depth. Yd. Ft. In.
COAL, dirty	0 1 10	216 2 8
Grey shale	1 0 0	
Hard post	0 1 2	
Grey metal with post and ironstone	1 2 0	
Dark metal	0 1 2	
COAL	0 1 6	220 2 6
Post and metal mixed	2 1 6	
Hard white post	1 1 0	
Grey metal	3 1 9	
Blue metal and ironstone	1 0 0	
Hard dark shale	0 2 3	
Blue metal and ironstone	1 1 0	
COAL	0 2 0	
Metal parting	0 1 3	
COAL	0 1 3	232 2 6
Blue metal and shaly post	4 1 2	
Very hard stone	0 0 11	
Dark metal, shale, and ironstone	4 2 1	
Hard post band	0 0 8	
Blue metal	0 2 0	
Hard post	0 2 9	
Blue metal	0 2 9	
Post band	0 0 8	
Soft blue metal	2 2 0	
Dark shale	1 0 4	
BULLHURST COAL { COAL	1 0 3	
BULLHURST COAL { Band	0 0 6	
BULLHURST COAL { COAL	2 0 9	252 1 4

SECTION No. 36.

No. 2 MOSS PITS, HARECASTLE.

From Mr. J. MacGowan.

Character of Strata.	Thickness. Yd. Ft. In.	Depth. Yd. Ft. In.
Soil and clay	3 0 0	
Blue marl	17 2 7	
Dark grey rock	1 2 6	
Black bass	0 2 10	
Dark grey rock	0 2 2	
Grey metal	1 0 4	
Very hard dark grey rock	1 2 0	
Grey metal	0 2 10	
Rock binds	3 1 5	
IRONSTONE	0 0 2	
Blue metal	0 2 1	
IRONSTONE	0 0 2	
Dirt	0 1 8	
IRONSTONE	0 0 3	
TOP TWO ROW COAL	1 0 3	

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
Dirt	0	1	6			
UNDER TWO ROW COAL	0	2	8			
Warrant	0	2	3			
Rock	2	2	0			
Strong rock binds	0	2	6			
Very strong metal	2	1	8			
MUCK COAL	1	0	0			
Rock binds	0	1	6			
Blue metal	2	1	8			
Ironstone bands	0	2	8			
Black bass	0	0	3			
COAL	0	0	1			
Soft grey metal	1	1	0			
Rock binds	2	0	0			
Very strong or BOWLING ALLEY ROCK	1	2	0			
Rock binds	5	1	0			
Blue metal	2	0	6	59	2	6
BOWLING ALLEY COAL { Coal 0 2 11; Dirt 0 0 3; Coal 0 0 8 }	1	0	10			
Warrant	1	0	0			
Rock	0	1	6			
Grey metal	3	2	6			
Rock binds	2	2	6	69	0	10
Rock binds	1	1	6			
Rock	0	1	0			
Rock binds	2	1	6			
Rock binds	5	0	0			
Grey metal	1	0	0			
Rock binds	4	0	0			
Rock	1	0	0			
Blue metal	0	0	3			
Rock binds	2	1	3			
Grey rock	3	1	3			
Blue metal with bands of ironstone	0	1	6			
Rock binds	1	1	0			
Grey rock	1	1	0			
Blue metal	1	1	6			
Grey metal	2	0	0			
Strong rock	0	1	6			
Blue metal	2	0	0			
Coal on deep side only (faulty)	0	1	0			
Black bass	0	1	0			
Coal on deep side only	0	1	0			
Blue metal	2	0	1			
IRONSTONE	0	0	2			
Blue metal	7	0	0	109	2	4
Black bass with bands of ironstone	5	1	6			
COAL—faulty	0	1	0			
Black bass	2	0	0			
COAL	0	1	8			
Warrant or fireclay	1	0	0			
Blue metal	1	1	1			

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
Strong rock binds	4	0	0			
Bastard whin	1	0	0			
Strong rock binds	12	0	0			
SEVEN FEET BANBURY COAL	2	1	1			
Warrant or fireclay	2	0	0			
Rock binds	3	0	0			
Strong rock	1	0	0			
Grey metal	2	0	3			
Black bass	1	2	0			
Strong rock	0	2	2			
Strong blue metal	2	0	0			
EIGHT FEET BANBURY COAL	2	2	0			
Rock binds	4	0	0			
Grey metal	2	0	0			
Cockle-shell bass	3	0	0			
Black bass	5	1	6			
Ironstone	0	0	3			
Dark blue metal	0	1	6			
COAL	0	0	3			
Black dirt	0	0	2			
COAL	0	1	0			
Rock binds	1	1	3	172	0	0
Heapstead	6	0	0	178	0	0

SECTION No. 37.

FAIR LADY PIT—MADELEY AND LEYCETT COLLIERIES.

From Mr. G. R. Hyslop.

Character of Strata.	Thickness. Yd.	Ft.	In.	Depth. Yd.	Ft.	In.
Clunch and basses	25	0	0			
BANBURY COAL	1	2	11			
Strong clunch	3	0	0			
Black bass	0	0	2			
Rock and rock bind	3	2	10			
Strong clunch	2	0	11			
Rock	1	1	0			
Rock binds	2	2	1			
Bass	0	1	6			
Rock binds	7	2	7			
COAL	0	1	2			
Black bass	0	0	9			
Clunch	1	2	0			
Cockle-shell bass	0	0	11			
Stone bind	3	1	8			
Grey metals	4	2	11			
Black bass	1	2	4			
COAL	0	1	10			
Warrant	0	2	11			
Bastard coal	0	1	4			

Character of Strata.	Thickness.			Depth.		
	Yd.	Ft.	In.	Yd.	Ft.	In.
Warrant	1	0	11			
Rock	9	0	6			
COAL	0	1	3			
Warrant	0	2	4			
Strong clunch	3	1	3			
Rock binds	6	2	10			
Rock	2	1	0			
Rock binds	8	0	8			
Bulldog stone	0	1	4			
BULLHURST COAL	5	1	0			
Hussle	0	0	5			
Bastard coal	0	0	9			
Warrant	0	1	9			
Rock	5	1	3			
Warrant	0	2	7			
COAL	0	0	4			
Strong clunch	3	1	8			

SECTION No. 38.

EDENSOR MARL PIT, NEAR HEATHCOTE ROAD, LONGTON.

Character of Strata.	Thickness.	
	Ft.	In.
Clay (partly Boulder-clay)	15	0
Grey marl with nodules of siderite	16	0
COAL	0	6
Clod	1	0
BASSEY MINE IRONSTONE	4	6
BASSEY MINE COAL	2	6

SECTION No. 39.

DAISY BANK BRICK AND MARL PIT, LONGTON.

Character of Strata.	Thickness.	
	Ft.	In.
White marl	10	0
Coal smut	0	3
Dark clod	1	3
White marl	3	0
Clod	2	0
Light-coloured and reddish marls	9	0
Dark-coloured grey marl	2	6
Mottled light red marl	6	0
Red marly grit	1	0
White marls with nodules	8	0
Grit in bands	1	4
Mottled marl	16	6
COAL	0	8
Black clod	0	9

Character of Strata.	Thickness	
	Ft.	In.
Grey marl with nodules of siderite	25	3
Black shale	2	6
White clay	1	3
COAL	2	3
White clay with streaks of clod	6	0
Grit	3	0
White clay	4	0
Grit	1	0

SECTION No. 40.
LONGTON HALL MARL PIT, LONGTON.

Character of Strata.	Thickness.	
	Ft.	In.
Grey grit	12	0
Yellow shales	3	0
COAL	0	8
Clod	1	8
COAL	1	3
Fireclay	2	0
Grit, plant remains	8	0
COAL	0	6
Green marl	2	6
Red marl	2	0
Bass	0	8
White marl	2	3
Limestone	0	4
White marl	2	0
Mottled red marl	15	0
Dark fireclay	7	0
COAL	0	8
Yellow clay	3	6
White marl with nodules of siderite	30	0
Grey grit	0	3
COAL	0	2
Shale	0	8
White marl	2	6
COAL	0	4
White marl	9	0
Bass	0	8
White marl	1	0
Bass	0	6

SECTION No. 41.
OLDFIELD MARL PIT, FENTON.

Character of Strata.	Thickness.	
	Ft.	In.
BASSEY MINE COAL	1	10
Fireclay and clay		
LITTLE ROW COAL	1	6
Fireclay with nodules of siderite	20	0
PEACOCK COAL	2	6
Shales with nodules of siderite	10	0

SECTION NO. 42.

WARRINGTON'S MARL PIT, FENTON LOW.

Character of Strata.		Thickness Ft.	In.
Sandy boulder clay		10	0
White clay	BLACK BAND GROUP	12	0
BASSEY MINE (gob)	BLACK BAND GROUP	7	0
BASSEY MINE COAL	BLACK BAND GROUP	2	6
White nodular marls	GREY COAL BEARING SERIES	20	0
LITTLE ROW COAL	GREY COAL BEARING SERIES	2	0
Fireclay	GREY COAL BEARING SERIES	3	0
Grit, dying out north	GREY COAL BEARING SERIES	12	0
Thin coal	GREY COAL BEARING SERIES	0	4
Grey marls with nodules of siderite	GREY COAL BEARING SERIES	15	0
PEACOCK COAL	GREY COAL BEARING SERIES	3	6
Fireclay			

SECTION NO. 43.

HEWITTS MARL PIT, FENTON LOW.

Character of Strata.	Thickness Ft.	In.
Boulder Clay	5	0
White clay (measurement not obtainable)		
WOOD, or FENTON LOW COAL	3	3
Black shales		
White marls with nodules of siderite	25	0
Mottled red marl	10	0
Black shales and thin coals	1	6
Fireclay	2	0
COAL	0	4
Fireclay	1	0
Irregular band of grit	12	0
Black shales	2	0
COAL	0	6
Black shales	1	6
Fireclay	1	0

SECTION NO. 44.

HAMPTON'S MARL PIT, HANLEY.

Character of Strata.	Thickness Ft.	In.
GLACIAL: White clay	5	0
GLACIAL: Coarse red sand	6	0
GLACIAL: Quicksand	4	0
Stiff white clay with coal streaks	6	0
Yellow shale with bands of grit and calcareous nodules	8	0
Black shales. *Anthracomya Phillipsi*	0	6

Character of Strata.	Thickness. Ft.	In.
Yellow shales	0	8
Black shales, with Entomostraca, Fish scales	0	1½
Grit	1	0
Mottled red marl	12	0
White clay	3	0
COAL	3	3
Fireclay	1	0
White clay (*Wad clay*) and yellow shales	2	4
Calcareous ironstone (nodular)	1	0
White clay	3	0
Calcareous ironstone (nodular)	1	0
Blue, purple, and white marl	8	6
Marl	0	6
Blue and purple marl	2	0
Coal smut	0	2
Grey grit	1	0
Yellow shales	2	6
Black shales with Fish scales	3	0
Fireclay with plants	6	0
White marl	6	0
Grey grit	0	6
White clay with plants	3	6
COAL	0	4
Fireclay	2	0
Coal shales	2	6
COAL	3	0
White marl	25	0
Mottled marl	5	0

SECTION No. 45.

CANNON STREET BRICK PIT, HANLEY.

Character of Strata.	Thickness. Ft.	In.
Yellow grit	30	0
COAL	2	6
White clay	12	0
Black shale	0	8
Grey shale	0	6
COAL	1	0
Grey marls	25	0
Rock	2	0
Mottled red mar	10	0
Deep purple mar	15	0
Clod	0	8
COAL	3	3
Light-coloured grey marl	20	0

SECTION NO. 46.

SHELTON MARL PIT, SOUTH OF ROWHURST PITS.

Character of Strata.	Thickness. Ft.	In.
Weathered clay	8	0
Black shales	12	0
Shales with *Anthracomya Phillipsi*	1	0
COAL	3	0
Fireclay	2	0
White clay	15	0

SECTION NO. 47.

BROOKFIELD BRICK PITS, GRANVILLE PLACE.

Character of Strata.	Thickness. Ft.	In.
White clay, Glacial	6	0
Blue marl	1	0
IRONSTONE	0	2
White marl	3	0
Limestone with Entomostraca	0	6
White marl	11	0
Black shale	0	6
White marl	4	0
Grit	1	0
White marl	2	0
Grit	1	0
White marl	3	0
Mottled red marl	1	3
Black shales, with Entomostraca, *Anthracomya Phillipsi*	0	4
Limestone, with *Spirorbis*, Entomostraca, Fish remains	1	0
Mottled marls	13	0
Grey grit	1	0
Grey marly shales with plants	6	0
Dark shale with plants	0	3
Grey marl with plants	1	0
Dark shale with plants	1	0
Grey marl with plants	2	0
Dark shales	2	0
Grey marl	2	0
Dark shale, *Anthracomya Phillipsi*	9	0
Laminated ironstone	9	0
BASSEY MINE COAL	1	6
Grey marls with nodules of siderite	12	0
Black shales	1	0
LITTLE ROW COAL	2	0
Clod	1	2
Grey marl with nodules of siderite	5	0
Grey shale	1	0
Dark shale	2	0

Section No. 48.

Nodens Marl Pit, north of Granville Place.

Character of Strata.	Thickness.	
	Ft.	In.
Black shales with *Anthracomya Phillipsi*	3	0
Fireclay with rootlets	3	6
Yellow clay	7	0
Coal smut	1	0
Fireclay	0	3
Shale with coal streaks	1	0
Grey marl	4	0
Grey, fine-grained grit	0	3
Grey marl	0	8
Grey marl. *Carbonicola Vinti*	0	2
Grey marl	1	0
Grey, fine-grained sandstone. *Carbonicola Vinti*	0	2
Black shales with *Anthracomya Phillipsi*	3	0
Dark, impure limestone, Entomostraca, *Anthracomya Phillipsi*	1	0
Grey marl	2	0
Mottled marl	14	0
Shale with coal streaks	1	0
Grey marls with nodules of siderite	5	0
Grit	1	0
Hard gritty marl	0	4
Mottled marl. *Anthracomya Phillipsi, Carbonia*	2	4
Black shales, *Carbonia*	0	4
Grey limestone, *Carbonia, Spirorbis*	1	2
Mottled light-coloured marls	22	0
Bassey Mine Ironstone	—	

Section No. 49.

Cobridge Marl Pit, Cobridge.

Character of Strata.	Thickness.	
	Ft.	In.
White clay	5	0
Grey limestone, Entomostraca, *Spirorbis*	1	2
Grey marls with nodules of siderite	15	0
Grey marl	5	0
Shale with coal smuts	0	6
Grey marls with nodules containing plant remains	14	0
Grey marls with nodules of siderite and black lines	8	0
Bassey Mine (Gob)	6	0
Bassey Mine Coal	2	0
Fireclay	2	0
Grey marls with nodules of siderite	13	0
Little Row Coal	1	6
Black shale	1	6
Grey marl	9	0
Black shale. *Anthracomya Phillipsi*	0	4
Grey marls with nodules of siderite	10	0

Character of Strata.	Thickness Ft.	In.
Hard grey grit	1	0
Grey marls with nodules of siderite		0
Grey marls	8	0
PEACOCK COAL		

SECTION No. 50.

MARL PIT NEAR RAILWAY, SOUTH-EAST OF BURSLEM STATION.

Character of Strata.	Thickness. Ft.	In.
Thin flags	3	0
Grey marls	3	0
Thin band of grit	0	2
Grey marl	1	2
Band of grit, *Carbonicola Vinti*	0	4
Grey marl	1	0
Grit	0	4
Grey marl	0	6
Grit	0	2
Sandy grey marl	1	6
Grit, plant remains	0	6
Grey marl	1	8
Grit, plant remains	0	1
Grey marl	0	8
Grit, plant remains	0	1
Grey marl	1	0
Grit, *Carbonicola Vinti*	0	3
Grey marl	0	8
Grit, *Carbonicola Vinti*	0	0½
Grey marl	3	0
Dark limestone. *Carbonia, Anthracomya Phillipsi*	1	0
Grey marl with nodules of siderite	13	0
Grey limestone. *Carbonia, Spirorbis*	1	0
Grey marl with nodules of siderite	26	0
BASSEY MINE, IRONSTONE (Gob)	5	0
BASSEY MINE COAL	1	10
Grey marls with nodules of siderite	14	0
LITTLE ROW COAL	1	10
Grey marl	12	0

SECTION No. 51.

GREENFIELD MARL PIT, TUNSTALL.

Character of Strata.	Thickness. Ft.	In.
Débris	8	0
COAL	1	0
Grey shales with bands of grit	10	0
Black shales. *Anthracomya Phillipsi*	2	0
COAL	0	8
Grey marls with nodules of siderite		

SECTION No. 52.
ADAM'S MARL PIT, TUNSTALL.
(West of Section No. 51.)

Character of Strata.	Thickness. Ft.	In.
Black shales and thin coals - - -	7	0
Grey marls - - -	4	0
Grey grit - - - - - -	0	10
Grey marl with bands of grit containing plants -	6	3
Dark limestone with *Carbonia* - - - -	0	3
Grey marls -	4	9
Grey shaly marl -	5	0
RED MINE IRONSTONE ? - - -	3	6
Grey marl with nodules of siderite - - - -	18	1

SECTION No. 53.
NEWFIELD MARL PIT, TUNSTALL.

Character of Strata.	Thickness Ft.	In.
Thin coals and shales - - -	4	0
Grey fireclay - - -	3	0
Yellow shales with nodules containing plants - -	7	0
Grit - - - - - -	2	0
Grey shales and thin bands of ironstone - - -	3	0
IRONSTONE - - - - - - - -	0	2
Black shale - - - - - -	2	6
Grey shale - - - - -	3	0
RED MINE IRONSTONE - - - - - -	6	6
RED MINE COAL - - - - - -	2	6
Grey marl - - - - -	20	0
Clod - - - - -	0	6
Grey marl - - - - - - - -	1	0
COAL - - - - -	3	0
Grey marl - - - - - - -	3	6
COAL - - - - - - - - - -	1	3

SECTION No. 54.
MARL PIT, HAMIL, BURSLEM.

Character of Strata.	Thickness Ft.	In.
Surface clay - - - - - - - - -	3	0
Flags - - - - - - - - -	1	0
White clay with bands of siderite - - - - -	4	6
Grey ironstone, irregular; plant remains - -	1	0
Yellow clays - - - -	2	0
Coal smut - - - - - - - - - - -	1	0
Black shales - - - - - - -	1	2
Laminated ironstone: *Anthracomya Phillipsi* -	3	6

Character of Strata.	Thickness.	
	Ft.	In.
Fireclay	1	0
Yellow clay	4	0
Flags and shales	6	6
Grey clay and three bands of ironstone	10	0
Grey ironstone	0	6
Grey shales and thin bands of grit with *Carbonicola Vinti*	7	2
Dark limestone, *Carbonia, Anthracomya Phillipsi*	0	10
Grey clay	3	2
Sandy grey clay	1	1
Grey clays with bands of grit	3	2

SECTION NO. 55.

SECTION OF NO. 1 BOREHOLE, BLURTON, NEAR LONGTON.

From Mr. G. A. Mitcheson.

Character of Strata.	Thickness,		
	Yds.	Ft.	In.
Clay and yellow rocky clay	3	0	3
Dark clod	4	2	3
COAL	0	1	0
Fireclay	0	1	0
Strong rock and binds	3	0	0
Hard rock	2	2	0
COAL	0	0	6
Fireclay	1	1	6
Binds	1	0	0
Ironstone	0	0	3
Strong rock binds	1	1	0
Rock and clod	2	1	0
IRONSTONE	0	0	4
Clod	0	1	0
Rock binds	2	0	0
Clunch	0	1	6
Hard rock with partings	6	1	6
Clod with thin ironstone	1	1	6
COAL and parting	0	0	9
Strong rock and clod	5	0	3
Clunch	0	1	6
COAL	0	1	9
Dark binds	0	1	0
Strong light rock	4	1	0
Clunch	0	0	10
Rock binds, clod and ironstone	1	0	6
Mottled ground, rock, and binds	2	1	0
Mottled ground and clod	1	2	6
Red marl	6	0	0
Grisley rock	1	0	0
Mottled rock	1	0	0
Rock marl and mottled marl	2	2	0
Strong rock marl	1	2	0
Grisley rock	0	1	6

Character of Strata.	Thickness.		
	Yd.	Ft.	In.
Marl and rock marl	3	0	0
Mottled marl	2	1	0
Rock	2	1	0
Blue rock	3	0	0
Brown parting	0	0	6
Rock marl	1	2	0
Mottled red yellow and white ground	7	0	0
Rock marl	1	1	0
Red and mottled ground	10	0	10

SECTION No. 56.

SECTION OF No. 2 BOREHOLE, BLURTON, NEAR LONGTON.

From Mr. G. A. Mitcheson.

Character of Strata.	Thickness.		
	Yd.	Ft.	In.
Soil and loose rock	2	1	0
Red rock	9	2	0
Hard jointy rock	1	1	0
Red rock	10	0	0
Red rock	1	2	0
Red marl	3	0	0

SECTION No. 57.

SECTION OF No. 3 BOREHOLE, BLURTON, NEAR LONGTON.

From Mr. G. A. Mitcheson.

Character of Strata.	Thickness.		
	Yd.	Ft.	In.
Soil and mixed clay	1	2	9
Red marl	7	2	0
Mottled ground	1	0	0
Light rock	3	0	0
Red marl	4	2	6
Mottled ground	3	0	6
Light rock	1	2	0
Mottled ground	1	2	0
Red marl	6	0	0
Mottled ground	5	1	0
Strong rock	0	2	6
Red marl	2	1	0
Mingled rock and parting	1	2	0
Blue rock	1	0	0
Mottled ground and blue rock	2	0	0
Mottled parting and blue rock	1	0	6
Mottled ground	2	0	0
Marl and rock marl	4	0	0
Mottled ground	20	0	0
Red and brown marl	4	1	0

Character of Strata.	Thickness. Yd.	Ft.	In.
Mingled rock	5	2	0
Blue and mottled rock	4	0	6
Red and mottled rock	5	2	0
Light peldon	2	1	0
Strong blue rock	2	0	0
Mottled rock	2	0	0
Red rock marl	25	1	0
Mottled marl	4	0	0
Red and mottled ground	4	0	9

SECTION NO. 58.

SECTION, EAST OF TUNNEL, MINERAL RAILWAY, GREAT CHELL.

(Inclination 15 degrees West.)

Character of Strata.	Thickness. Ft.	In.
Black shales with thin flags and ironstone bands	12	0
Grey shales with nodules of siderite	24	0
Black shale with Entomostraca	0	8
Coal smut	0	3
Fireclay and marl mixed	21	0
Ironstone in bands, Entomostraca, *Naiadites*, *Spirorbis*	3	0
Fireclay and shale	4	0
Black shale and ironstone bands, *Naiadites*	6	0
Black shale	5	3
IRONSTONE, compact	0	7
Black shale	12	0
COAL	3	2
Shale	1	7
COAL	0	3
Fireclay	2	6
Grey sandy shale	4	0
Clod	0	4
Grey shales	3	0
Grey shales with plant remains	0	6
Black shales	2	6
Grey shales with plant remains	1	4
Grey shales with star-like coal streaks	12	0
Orange grit	15	0
Shales with layers of compressed coal	6	0
Fireclay	2	0
Fault down west.		
Grey flags	25	0
Sandy shales	12	0
Black shales	10	0
Sandy shales (imperfectly seen)	40	0
ASH OR ROWHURST COAL { COAL	3	3
ASH OR ROWHURST COAL { Parting	1	0
ASH OR ROWHURST COAL { COAL	3	0

SECTION No. 59.

RAILWAY CUTTING, NEWCASTLE-UNDER-LYME STATION.

(Section commences at west end of platform.)

Character of Strata.	Thickness Ft.	In.
Sandstone (not well exposed)	12	0
Yellow flaggy sandstone	3	0
Yellow shales	12	0
COAL	1	8
Fireclay	2	6
Grey shales	15	0
Yellow shales	13	0
Grey sandstone	1	0
COAL	0	8
Fireclay	1	4
White clay	6	0
Sandstone, grey	9	6
Flaggy sandstone	5	0
Shales and clay	16	0
Sandstone	5	0
Grey shales	3	0
Small fault down west.		
Sandstone	10	0
Flaggy sandstone	6	0
Sandstone	4	0
Shales	6	0
Sandstone	4	10
Grey shales with plants	9	0
COAL	0	2
Fireclay	0	3
COAL	1	4
Shale	2	0
Sandstone	3	0
Sandy shale	6	0
Flaggy sandstone	5	0
Grey shales	6	0
Flags	8	0
Yellow shaly flags	3	0
Black shales—*Carbonia*, abundant	2	6
Limestone *Carbonia*	0	11
Black shales, *Carbonia*, abundant	1	3
Grey flags passing into limestone	1	0
Grey clay	4	0
Mottled red marls (Etruria marls)	8	0

SECTION No. 60.

HIGHFIELDS TILERIES, WOOLSTANTON.

Character of Strata.	Thickness Ft.	In.
Yellow flags and shales	20	0
Yellow shales, fish scales	0	6
Red shales, *Carbonia*	1	6
Black shales, *Carbonia*, fish scales	0	8

Character of Strata.	Thickness.	
	Yd. Ft.	In.
Red shales - - -	2	0
Red limestone, *Carbonia*, fish remains -	1	0
Yellow shales - - - - -	0	8
Blue limestone, *Anthracomya calcifera, Carbonia*	0	8
Yellow shales -	1	0
Purple marls - - -	35	0
Greenish yellow grit (base not seen) -	2	0
Brecciated limestone - -	1	0
Red marl - -	—	

SECTION NO. 61.

ROAD CUTTING, BUTTERTON NEW FARM.

Character of Strata.	Thickness	
	Ft.	In.
Yellow flags - - -	10	0
Gap (occupied by grey shales and a thin coal) -		
Yellow flags - -	24	0
COAL - -	1	6
Fireclay	1	0
Grey shales - - - - - - -	20	0
Red shales, *Carbonia, Estheria tenella*, fish remains -	0	6
Red limestone, irregular, fish remains, *Carbonia*	1	0
Red shales -	1	0

SECTION NO. 62

RAILWAY CUTTING, KEELE PARK RACING STATION.

To be corrected for an inclination 25.S.

(Section commences near south end of platform.)

Character of Strata.	Thickness.	
	Ft.	In.
Lavender red calcareous hard sandstones -	30	0
Ochreous and red marls with concretionary nodules -	45	0
Hard calcareous light red and greyish sandstone	1	4
Red marl—partly obscured -	33	0
Hard red calcareous sandstones -	1	2
Red sandy marl -	83	0
Slightly ochreous red marl with concretions - - -	48	0
Ochreous mottled marl with thin bands of red and grey shales and small concretionary nodules - -	77	0
Banded calcareous sandstone -	0	4
Red marl - - - -	2	6
Calcareous breccia - - - - - -	1	1
Sandy red marl and red marl - - -	274	0
Fine grained red flaggy sandstone with occasional band of thin grey flags - - - - - - - - -	60	0
Red compact thick-bedded sandstone with lenticular bands of calcareous breccia in the body of the rock. Tunnel for 102 feet. Red marls are seen entering tunnel at the north end	60	0

Character of Strata.	Thickness.	
	Ft.	In.
Light lavender and greyish thin flags	78	0
PORCELLANOUS WHITE LIMESTONE	0	4
Thin flags	4	0
PORCELLANOUS WHITE LIMESTONE	1	0
Light red thin flaggy sandstone	18	0
Red marl	60	0
Grey very sandy marl	1	0
Thin bedded red flags	18	0
Flaggy soft lavender red sandstone	96	0
Thin bedded light red and grey micaceous sandstone with occasional 6 in. bands of hard calcareous sandstone	63	0
Mottled marl with 4 in. bands of a highly calcareous rock	60	0
BLACK LIMESTONE with *Spirorbis* and *Carbonia*	0	11
Red and flaggy sandstone and sandy marls	39	0
Thin bedded lavender red flags	27	0
Red sandy marl with hard red flags in middle	90	0
Red sandy marl with hard red flags in middle	54	0
Purple massive sandstone with white patches	111	0

SECTION No. 63.
Keele Estate.
Boring No. 5.
From Mr. J. Boothby.

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Soil	0	6		
Brown stony clay	14	6		
Red marl	75	0		
Brown marl	13	0		
Red marl	75	6		
Grey metal	2	0		
Whin	0	3		
Grey post	1	3		
IRONSTONE	0	5	182	2
Grey metals	8	6		
Red marl	79	0		
Grey post	3	0		
Red marl	39	0		
Grey post	10	0		
Red marl	24	0		
Grey post	6	6		
Red metal	12	0		
Grey metal	6	0		
Grey post	6	0		
Red metal	4	6		
Grey metal	2	0		
COAL	0	6	383	2
Grey metal	6	6		
Red metal	9	0		
Grey post	2	0	400	11

Character of Strata.	Thickness. Ft. In.	Depth. Ft. In.
IRONSTONE	0 3	
Grey metal stone	1 0	
IRONSTONE	0 8	
Grey metal	0 4	
IRONSTONE	0 9	403 8
Shale	0 4	
IRONSTONE	2 1	
Shale	1 6	
COAL	0 8	408 3
Grey metal	4 3	
IRONSTONE	1 11	414 5
Grey metal	3 0	
IRONSTONE	0 2	417 7
Grey metal stone	0 10	
IRONSTONE	0 3	418 8
Grey metal stone	2 9	
COAL	0 3	421 8
IRONSTONE	0 4	422 0
Grey metal stone	1 9	
IRONSTONE	0 3	424 0
Grey metal stone	1 4	
IRONSTONE	0 2	425 6
Grey metal	0 6	
IRONSTONE	0 2	426 2
Grey metal stone	1 0	
Grey post	3 0	
Grey metal stone	2 0	
IRONSTONE	0 3	432 5
Grey metal stone	1 0	
IRONSTONE	0 2	433 7
Grey metal	2 0	
IRONSTONE (supposed black band ironstone)	1 6	437 1
COAL	2 3	439 4
Grey metal	3 0	

SECTION No. 64.

KEELE ESTATE.

Boring No. 6.

O.D. 480 Feet (Approx.)

From Mr. J. Boothby.

Character of Strata.	Thickness. Ft. In.	Depth. Ft. In.
Soil	0 6	
Brown stony clay	8 6	
Sand	2 6	
Red metal	20 6	
Grey post	20 0	
Red marl	49 0	
Grey post	4 0	

Character of Strata.	Thickness. Ft.	In.	Depth. Ft.	In.
Red metal	24	0		
Grey post	9	6		
Red metal	22	6		
Grey post	5	6		
Red metal	148	0		
Grey post	22	0		
Red metal	9	0		
Grey metal	1	0		
Red metal	2	0		
Grey post	26	0		
Grey metal	5	0		
IRONSTONE	0	8	380	8
Grey metal stone	1	0		
IRONSTONE	0	6	382	2
Grey metal stone	1	0		
IRONSTONE	1	0	384	2
Grey marl	22	6		
IRONSTONE	3	9	410	5
Grey metal	7	6		
Grey post	14	0		
Grey metal	1	0		
Red metal	12	0		
Grey post	2	6		
IRONSTONE	0	2	447	7
Grey metal stone	3	6		
Red metal	2	0		
Grey metal stone	6	0		
Red metal	4	6		
Grey metal	1	0		
IRONSTONE	0	3	464	10
Grey metal	2	0		
Coal	0	3	467	1
Grey metal	6	6		
Red metal	7	6		
Grey post	6	0		
IRONSTONE	0	3	487	4
Grey metal stone	0	9		
IRONSTONE	0	2		
Grey metal stone	0	6		
IRONSTONE	1	9		
Grey metal	3	4		
Dark metal	0	6		
COAL	0	7	494	11
Grey metal	7	0		
IRONSTONE	0	8	499	8
Grey metal stone	8	6		
COAL	0	4	509	0
Grey metal	2	0		
IRONSTONE	0	2		
Grey metal stone	2	0		
IRONSTONE	0	2		
Grey metal stone	1	0		
Grey post	2	0		

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Grey metal stone	0	6		
IRONSTONE	0	2		
Grey metal stone	0	10		
IRONSTONE	0	2		
Grey metal stone	2	3		
IRONSTONE—black band ?	1	9		
COAL	2	3	521	9
Grey metal stone	12	0		
IRONSTONE	0	3		
Grey metal	0	6		
IRONSTONE	0	3		
Grey metal stone	2	6		
IRONSTONE	0	2		
Grey metal	0	9		
IRONSTONE	0	2		
Grey metal stone	1	10		
Black metal	0	6		
Grey metal stone	2	2		
Grey post and whin	0	6		
Grey metal	1	6		
Red metal	5	0		
Grey metal	5	6		
IRONSTONE	0	9		
COAL	0	6		
Grey metal	3	0		
Grey metal stone with post	19	0		
Dark metal with coal	2	4		
COAL	0	6	581	5
Grey metal	2	0		
Grey post with whin	2	6		
Grey metal	0	6		
IRONSTONE	0	6	586	11
Grey metal	1	0		
Hard grey post and whin	12	0		
Grey metal	14	9		
COAL	2	3		
Grey metal	2	0		
COAL	2	9	621	8

SECTION No. 65.
KEELE ESTATE
Boring No. 7.
From Mr. J. Boothby.

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Brown clay	6	0		
Red marl	9	0		
Red post	18	0		
Red post	54	0		
Red metal	45	0		

———	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
COAL	0	7	132	7
Grey metal	21	0		
Grey post	8	0		
Grey metal	10	6		
IRONSTONE	1	3	173	4
COAL	0	3	173	7
Grey metal	18	0		
COAL	2	1	193	8
Grey metal	4	0		
Grey post	5	0		

SECTION NO. 66.

MEIR BORING, STAFFORDSHIRE POTTERIES WATERWORKS.

O.D. 610 Feet (approx.)

From Mr. G. D. Harrison.

Character of Strata	Thickness		Depth.	
	Ft.	In.	Ft.	In.
Marl (with little water)	150	6	150	6
Red sandstone and marl (mixed)	2	0	152	6
Red sandstone (with water)	14	0	166	6
White sandstone*	2	0	168	6
Red sandstone (with water)	30	0	198	6
Marl (hard, dry)†	47	0	245	6
Soft marl	1	0	246	6
Hard red sandstone (with much water)	40	0	286	6
White sandstone (with a large quantity of water)	6	0	292	6
Red sandstone, with beds of marl	88	0	380	6
Red sandstone‡	119	0	499	6

SECTION NO. 67.

WELL AT THE ASYLUM, CHEDDLETON (535 FEET ABOVE O.D.).

The well is 112 feet deep, composed of 15 feet clay and decomposed Bunter, and nearly 100 feet of solid Bunter overlying Carboniferous shales. The water stands at 76 feet from the surface and about 10 feet above the alluvium of the Churnet below. The base of the Bunter is some 25 to 30 feet below the bottom of the alluvium.

* Very fine grained, according to Mr. Harrison.

† A specimen of this was red, hard, and compact.

‡ Specimens of the lowest part of this showed a hard conglomerate with many pebbles, often close together, the largest being an inch or more in length, mostly, but not all, well rounded, in a light pinkish-brown, hard, coarse-grained sandstone-matrix. Only the lowest beds were said to be pebbly. Specimens shown from the same rock higher up were essentially the same sandstone without the pebbles. According to Mr. Harrison, the greater part of the red sandstone in the boring was of this nature, and there was nothing like the white Keuper Sandstone of the Meir Station section.

WELL AT PAPER MILL BETWEEN CHEDDLETON AND THE STATION.

		Ft.	In.
	Made Ground	4	0
	River Level.		
Alluvium.	Blue Clay	1	6
	Peat	1	0
	Blue Clay	3	6
	Brown Sandy Clay	5	6
Trias.	Loose Red Sandstone and Peebles	22	6
	Bands of Red Sandstone and Red Marl	45	0

Pumps 400,000 gallons a day ; 300,000 gallons checks springs above river level, but the spring flows again during night : 150,000 gallons had no visible effect. Pumps to 20 feet below river, but it fills to surface during the night.

SECTION No. 68.

BORING ON TOWN HOUSE FARM, ALSAGER ESTATE.

O.D. 320 Feet (approx.).

From Mr. F. Rigby.

Character of Strata.	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Soil	0	8	0	8
Sand	4	4	5	0
Marl	34	6	39	6
Sand and gravel	10	6	50	0
Sand	6	6	56	6
Red loam	3	6	60	0
Large gravel	4	0	64	0
Grey shale	11	0	75	0
Red loam	5	0	80	0
Grey shale	13	6	93	6
Red loam	5	0	98	6
Grey shale	7	6	106	0
Red shale	12	6	118	6
Grey shale	12	0	130	6
Red shale	11	6	142	3
Grey shale	14	6	156	6
Red shale	7	6	164	0
Red shaly rock	32	0	196	0
Grey rock	4	0	200	0
Red shaly rock	18	0	218	0
Red loam	52	0	270	0
Grey shaly rock	2	6	272	6
Red loam	49	6	322	0
Red and grey rock	113	0	435	0
Grey rock	2	0	437	0
Red and grey rock	85	0	522	0
Red sandstone	8	0	530	0
Grey rock	5	0	535	0
Red sandstone	18	0	553	0
White sandstone (tapped a considerable quantity of water	13	0	566	0

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Red sandstone	28	0	594	0
White sandstone	4	0	598	0
Red sandstone	117	0	715	0
White sandstone	20	0	735	0
Red sandstone	23	0	758	0
Red shale	9	0	767	0
Red sandstone	7	0	774	0
Red shale	16	0	790	0
Red sandstone	16	0	806	0
White sandstone	1	0	807	0
Red sandstone	25	0	832	0
Red and grey shale	2	0	834	0
Red shale and sandstone	10	0	844	0
Grey rock	5	0	849	0
Red shaly rock	8	0	857	0
Grey rock	2	0	859	0
Red sandstone	1	0	860	0

SECTION No. 69.

BORING ON HOWFORD BRIDGE ESTATE, BUGLAWTON.*

From Mr. W. Binney.

Character of Strata.	Thickness.	
	Ft.	In.
Red marl	5	0
Grey sandstone	2	0
Red marl	3	3
Grey marl	7	0
Red marl	10	0
Red stone	0	4
Grey stone	2	0
Red marl	0	8
Grey marl	4	0
Red marl	3	0
Red stone	0	1
Red marl	0	2
Grey marl	20	0
Red marl	6	0
Red stone	0	2
Red marl	4	0
Gypsum	7	0
Red marl, with 4 inches of ironstone	1	6
Gypsum	4	0
Red marl	6	0
Red stone	0	1
Grey marl	5	0
Grey stone	0	6
Red marl	3	0
Grey stone	0	3

* Reprinted from *Mem. Geol. Surv.*, Geology of the Country round Stockport, Macclesfield, Congleton and Leek, page 41.

Character of Strata.	Thickness. Ft.	In.
Grey stone	0	6
Red stone	0	6
Red marl	5	0
Grey stone	0	4
Red stone	3	0
Red marl	4	0
Grey stone	0	4
Red marl	0	8
Red stone	0	2
Grey stone	0	6
Red stone	0	3
Red marl	2	0
Red marl	0	3
White marl	0	2
Grey stone	0	1
Red marl	2	2
Red marl	2	0
Grey marl	2	1
Grey bass shale	6	0
Grey marl	2	0
Grey bass shale	2	0
Dark rock	0	6
Grey stone	0	6
Red marl	5	0
Black bass	1	10
Grey stone	2	2
Grey rock	26	0

THE CHEADLE COALFIELD.

SECTION No. 70.

BOREHOLE NORTH OF CHEADLE GASWORKS.

O.D. 600 Feet.

From Mr. W. Lockett.

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Surface soil	0	9	0	9
Sand and gravel	5	0	5	9
Red clay and gravel	2	0	7	9
Variegated marly clay	11	5	19	2
Variegated sandy marl	5	0	24	2
Variegated sandy marl with stone	3	6	27	8
Variegated sandy marl with ironstone balls	3	6	31	2
Variegated marl with ironstone balls	2	0	33	2
Yellow sandy clay and stone	3	10	37	0
Blue marly clay	5	6	42	6
Grey fireclay with ironstone balls	8	3	50	9
Soft black shale	1	3	52	0
Dark grey shale with ironstone balls	1	9	53	9
COAL	1	11	55	8
Grey fireclay	0	9	56	5
COAL	0	8½	57	1½
COAL and dirt	0	5½	57	7
Black dirt with little coal	0	11	58	6
Grey fireclay	1	11	60	5
Grey shale	2	7	63	0
Grey shale	1	9	64	9
Grey sandy shale	11	7	76	4
Soft black shale	1	2	77	6
Soft dark shale	2	3	79	9

Character of Strata.	Thickness. Ft.	In.	Depth. Ft.	In.
Soft grey shale	4	7	84	4
COAL and dirt	0	11	85	3
Soft grey shale with veins of coal	1	5	86	8
COAL	1	11	88	7
Black dirt	0	2	88	9
Grey fireclay	0	8	89	5
Coal veins	0	1	89	6
Grey fireclay	1	6	91	0
Bluish shale	3	8	94	8
Bluish shale with ironstone balls	4	2	98	10
Soft dark grey shale	0	7	99	5
Bluish shale	1	4	100	9
Bluish jointy gritstone	0	3	101	0
Dark grey shale with sandy bands, broken and jointy	2	3	*104	1
Dark grey shale with sandy bands and ironstone balls	20	11	125	0
Dark grey shale, broken	4	0½	129	0½
Grey ironstone	0	4½	129	5
Soft dark shale with ironstone balls	3	7	133	0
Soft black shale with ironstone balls	11	0	144	0
Broken black shale	14	6	158	6
COAL, soft	1	7	160	1
Black dirt	0	9	160	10
Dark grey fireclay	2	1	162	11
Dark shale	3	8	166	7
Dark grey fireclay	0	8	167	3
Dark shale with ironstone balls	1	9	169	0
Dark grey sandy shale	2	5	171	5
Soft dark shale with ironstone balls	2	8	174	1
Black smutty shale	1	8	175	9
Black shale	0	2	175	11
Soft dark shale with ironstone balls	5	7	181	6
Black smutty shale	2	0	183	6
COAL	0	3	183	9
Black smutty shale	0	4	184	1
COAL	1	4	185	5
Grey fireclay	0	6	185	11
Grey sandy shale	3	0	188	11
White sandstone	1	3	190	2
Grey sandy shale	5	1	195	3
Hard grey sandstone	4	1	199	4
Dark grey sandy shale	3	6	202	10
Dark shale with ironstone balls	11	11	214	9
Black shale	0	6	215	3
Dark shale with ironstone balls	0	10	216	1
Black shale with ironstone balls	3	3	219	4
Dark shale with ironstone balls	0	8	220	0
Broken black shale	2	7	222	7
Bluish shale with ironstone balls	3	6	226	1
Grey sandy shale	2	10	228	11
Dark grey shale with ironstone balls	9	5	238	4
COAL	2	0	240	4
Grey fireclay	2	6	242	10

* So in original MS.

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Grey fireclay with ironstone balls	5	2	248	0
Grey fireclay with veins of dirty coal	2	7	250	7
Grey fireclay with ironstone balls	3	2	253	9
Dark grey shale with ironstone balls	11	5	265	2
Black shale with ironstone balls	1	0	266	2
Dark grey shale with ironstone balls	2	0	268	2
Grey shale with ironstone balls	4	10	273	0
Dark grey shale with ironstone balls	11	6	284	6
Broken black shale	1	9	286	3
Dark grey shale	0	4	286	7
Black shale	0	5	287	0
Dark grey shale with ironstone balls	5	8	292	8
Black shale	0	3	292	11
COAL	3	4	296	3
COAL, harder	1	3	297	6
Black shale	0	1	297	7
Hard grey sandy shale	2	3	299	10
Grey sandy shale	12	4	312	2
Grey sandstone	6	6	318	8
Grey sandy shale	1	3	319	11
Dark grey shale with ironstone bands and balls	7	11	327	10
Dark shale	0	6	328	4
Black shale	0	6	328	10
Bluish shale with ironstone balls	1	6	330	4
Soft dark shale with veins of coal	0	7	330	11
Bluish shale with ironstone balls	3	9	334	8
Grey sandstone	0	10	335	6
Bluish shale with ironstone balls	5	4	340	10
Black shale with ironstone balls	3	8	344	6
COAL, Poor	0	7	345	1
Grey fireclay	0	2	345	3
Soft dark grey shale with ironstone balls	7	3	352	6
Soft dark shale with ironstone balls	4	9	357	3
Black shale	0	6	357	9
Bluish shale with ironstone balls	0	7	358	4
Black shale	3	4	361	8
Dark grey shale with ironstone balls	2	5	364	1
Black shale	0	8	364	9
Dark grey shale with ironstone balls	3	0	367	9
Dark grey sandy shale	9	1	376	10
Dark grey sandy shale with ironstone balls	5	0	381	10
Dark shale with ironstone balls	5	2	387	0
Dark shale	6	0	393	0
Dark shale with ironstone balls and bands of black shale	2	0	395	0
Broken black shale with ironstone balls	3	1	398	1
COAL and dirt	0	11	399	0
Dark grey fireclay	0	9	399	9
Grey fireclay	5	11	405	8
Dark grey sandy shale	5	10	411	6
Dark shale	3	4	414	10
Dark shale with ironstone balls	4	7	419	5
Dark grey sandy shale	1	5	420	10

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Grey sandstone	0	8	421	6
Dark shale	0	6	422	0
Bluish grey shale	1	6	423	6
Black shale	4	0	427	6
Bluish grey shale	5	3	432	9
Bluish grey shale with ironstone balls	7	3	440	0
Dark shale	1	0	441	0
Bluish grey shale with ironstone balls	1	6	442	6
Dark shale	2	0	444	6
Bluish grey sandy shale	3	0	447	6
Dark grey shale with ironstone balls	2	0	449	6
Dark grey sandy shale	1	7	451	1
Bluish grey sandstone	1	3	452	4
Dark grey sandy shale	1	2	453	6
Grey gritstone	1	6	455	0
Dark grey sandy shale	3	0	458	0
Bluish grey shale	4	6	462	6
Dark grey shale with ironstone balls	4	6	467	0
Dark shale	2	9	469	9
Black shale with ironstone bands	3	5	473	2
Bluish shale	4	0	477	2
COAL	0	5	477	7
Dirt	0	2	477	9
COAL and dirt	0	8	478	5
Dirt	0	4	478	9
COAL, dirty	0	10	479	7
Dirt	0	7	480	2
COAL, dirty	0	6	480	8
COAL	0	11	481	7
Dirt	0	3	481	10
COAL and dirt	0	3	482	1
COAL, dirty	0	4	482	5
COAL	1	5	483	10
Dirt	0	6	484	4
Dark grey fireclay	1	0	485	4
Dark grey sandy shale	2	8	488	0
Bluish grey gritstone	3	0	491	0

SECTION No. 71.

1. DELPHOUSE COLLIERIES, CHEADLE.

From Mr. W. Lockett.

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Coal and smut	2	6	2	6
Marl	8	6	11	0
2 YARD ROCK	16	0	27	0
Grey shale	17	0	44	0
2 YARD COAL	5	6	49	6
OUSTER COAL AND PRICKING	2	8	52	2
Clunch	6	1	58	3

Character of Strata.	Thickness. Ft.	In.	Depth. Ft.	In.
Roach and rock binds	18	4	76	7
Sandy rock, not bedded, but hard	27	0	103	7
GETLEY COAL (useless)	2	0	105	7
Hard sandy rock	13	0	118	7
Soapy grey shale (fossil marl and black bat roof)	7	0	125	7
HALF YARD COAL	2	6	128	1
Clunch	6	0	134	1
Roach and rock binds	16	0	150	1
Hard white rock with black streaks	24	0	174	1
Grey shale	12	0	186	1
Black shale roof	0	6	186	7
YARD COAL	3	9	190	4
Fireclay	1	6	191	10
Hard clunch	6	0	197	10
LITTLEY ROCK	15	0	212	10
Hard white rock	8	0	220	10
Grey shale (fossil bed at base)	19	0	239	10
LITTLEY COAL	2	9	242	7
Grey clunch	6	0	248	7
FOUR FOOT ROCK	12	6	261	1
Grey shale	14	9	275	10
FOUR FOOT COAL	3	6	279	4

SECTION No. 72.

FOXFIELD SHAFT, TWO MILES W.N.W. OF CHEADLE.

From Mr. A. Fisher.

Character of Strata.	Thickness. Ft.	In.	Depth. Ft.	In.
Clay and marl	24	0	24	0
DILHORNE COAL	6	0	30	0
Seat	4	6	34	6
Grey shale	4	9	39	3
COAL, 9 in. Black clunch, 7 in. COAL, 8 in.	2	0	41	3
Seat and rock binds	5	6	46	9
Grey shale	9	0	55	9
Dark brown shale and pebbles	4	6	60	3
Black stone, 3 in. COAL, 5 in.	0	8	60	11
Seat	2	0	62	11
Strong rock binds	5	0	67	11
Grey shale	9	0	76	11
Dark grey clunch	3	2	80	1
Black shale and stone bands	4	4	84	5
Grey shale	4	0	88	5
OUSTER COAL, 5 in. Pricking, 3 in.	0	8	89	1
Hard grey rock	2	0	91	1
Soft grey rock	2	6	93	7
Strong roach	4	6	98	1
Hard grey rock	4	6	102	7
Roach	20	0	122	7

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	F.	In.
Strong grey metal	10	6	133	1
Black shales	7	6	140	7
Stone, COAL and rattlecock (cannel shale)	1	5	142	0
Fireclay	7	6	149	6
Dark shale	14	0	163	6
Grey shale	10	0	173	6
Rock	9	0	182	6
Grey shale	18	0	200	6
Black shale	8	0	208	6
Grey shale	5	3	213	9
Moonshine (shale full of slickens)	4	3	218	0
COAL, 1 ft. 3 in. Pricking, 6 in. STINKING or COAL, 2 ft. ALECS COAL	3	9	221	9
Seat	3	0	224	9
Strong binds	6	0	230	9
Strong rock	27	6	258	3
Strong binds	18	0	276	3
FOXFIELD COAL	1	8	277	11
Pricking	0	8	278	7
Strong clunch	3	0	281	7
Strong grey binds	17	0	298	7
Red roach	13	6	312	1
Chocolate rock	14	0	326	1
Chocolate metals	7	0	333	1
Grey shale, black at base	5	0	338	1
MANS COAL	1	5	339	6
Black seating	2	6	342	0
COAL	0	8	342	8
Clunch	3	0	345	8
Black shale	3	6	349	2
Strong clunch	5	0	354	2
Grey sandstone	2	0	356	2
Binds	4	0	360	2
Grey shale	5	6	365	8
COAL and shale	0	6	366	2
Clunch	3	0	369	2
Brown yards	5	0	374	2
Grey yards	25	0	399	2
Grey metals	18	0	417	2
Black shale	1	6	418	8
Grey shale	3	0	421	8
Rock (sandstone)	4	0	425	8
Grey shale	30	0	455	8
Black shale	1	3	456	11
Grey shale, black at base	15	3	472	2
COBBLE COAL	1	3	473	5
Strong clunch, full of iron balls	7	6	480	11
Rock	4	0	484	11
Grey metals	7	6	492	5
Dark shales, black base	37	6	529	11
COAL	1	1	531	0
Strong clunch	9	6	540	6
Binds	10	6	551	0

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Grey metals, full of iron balls-	9	6	560	6
Black shale and slickensides -	3	0	563	6
Clunch, flinty rock boulders -	3	0	566	6
Rock binds -	7	0	573	6
Grey metal, full of iron balls -	31	0	604	6
Black shale and stone of coal -	1	0	605	6
Dark clunch -	4	0	609	6
Metals and binds	14	0	623	6
Grey shale -	2	0	625	6
RIDER COAL -	1	6	627	0
Clunch, soft top -	3	6	630	6
Grey binds	9	0	639	6
Grey sandstone -	24	0	663	6
Dark shale on clunch	8	6	672	0
Hard rock -	7	6	679	6
Strong grey metal, shale in middle	43	0	722	6
Grey shale -	12	0	734	6
Black shale -	14	0	748	6
WOODHEAD COAL -	2	9	751	3
Pricking, 9 in. Duster coal, 3 in.-	1	0	752	3

SECTION No. 73.

CHEADLE PARK COLLIERY, ONE MILE N. OF CHEADLE.

From Mr. S. Offer.

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Soil and clay -	8	6	8	6
Strong fireclay	62	0	70	6
ALECS OR STINKING COAL (two dirt seams of 9 and 5 inches) -	6	0	76	6
Soft clunch -	7	0	83	6
Sandstone	11	0	94	6
Grey shale -	20	6	115	0
FOXFIELD COAL	1	4	116	4
Clunch -	8	0	124	4
Sandstone -	11	0	135	4
Grey shale -	22	0	157	4
Black shale -	1	0	158	4
COAL -	1	0	159	4
Clunch -	5	0	164	4
Sandstone	8	0	172	4
Grey roach -	33	0	205	4
COAL -	0	9	206	1
Clunch -	2	0	208	1
Grey shale	15	0	223	1
Sandstone -	13	0	236	1
Grey shale -	18	0	254	1
Black shale -	1	6	255	7
Grey shale -	15	0	270	7

Character of Strata.	Thickness. Ft.	In.	Depth. Ft.	In.
COBBLE COAL - - - - - - - -	2	2	272	9
Clunch, etc. - - - - - - - - -	1	0	273	9
Clunch - - - - - - - -	21	0	294	9
Dark shale - - - - -	17	0	311	9
Sandstone - - - - - - - -	18	6	330	3
Grey shale - - - - - - - - -	7	0	337	3
COAL - - - -	0	3	337	6
Clunch - - - - -	4	0	341	6
Grey shale - - -	15	0	356	6
Sandstone - - -	8	0	364	6
Grey roach - - -	21	0	385	6
Grey shale - - - - - -	7	0	392	6
Sandstone - - -	14	0	406	6
Grey shale - - - -	17	6	424	0
RIDER COAL - - - - - -	1	4	425	4
Clunch - - - - - -	3	0	428	4
Grey shale - - - - -	6	0	434	4
Red sandstone -	21	0	455	4
Strong roach -	41	0	496	4
Grey shale - - - -	13	6	509	10
Black shale or bass - - - - - -	9	6	519	4
WOODHEAD COAL	2	11	522	3

SECTION No. 74.

BIRCHES COLLIERY.* S.E. OF CHEADLE.

Character of Strata.	Thickness. Ft.	In.	Depth Ft.	In.
Soil and brick clays -	12	0	12	0
Fireclay - - -	3	0	15	0
Clunch and binds - - -	162	0	177	0
COBBLE COAL -	2	10	179	10
Fireclay- - -	6	0	185	10
Rock and rock binds - -	6	6	192	4
White and red micaceous sandstone -	105	0	297	4
Rider rock - - - -	12	0	309	4
Roach - - - - -	12	0	321	4
Black shale	2	0	323	4
RIDER COAL	1	6	324	10
Fireclay- - -	1	0	325	10
White rock - -	29	0	354	10
Roach, fine laminated sandstone - - -	63	0	417	10
Red and grey marl. Balls of red sandstone	9	6	427	4
Black shale. The Bass - -	7	6	434	10
WOODHEAD COAL - -	3	2	438	0

* Taken from the "History of Cheadle," by R. Plant, page 297. If the account is correct there is far more hard or sandy material present here than in the area to the west and north. The Cobble Coal is unusually thick. The thickness of the Woodhead Coal includes the Pricking and Ouster Coal beneath, not usually reckoned in the thickness of the seam.

SECTION No. 75.

PARK HALL COLLIERY, CHEADLE.

(Communicated by Mr. J. R. HAINES, to depth of 583 feet 10 inches, and by Mr. G. G. Almond, below that depth).

Character of Strata.	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Pit top raised	9	0		
Clay	8	0		
Grey shale	13	0		
SWEET COAL	0	9	30	9
Marl	4	0		
Hard rock	14	0		
Grey shale, with rock	78	0		
STINKING COAL	3	9	126	9
Marl	4	0		
Rock	11	0		
Grey roach	39	0		
MAN'S COAL	1	6	184	6
Strong clunch	4	6		
Grey roach	7	6		
Black shale	3	6		
Clunch	5	0		
Grey roach	11	4		
COAL	0	2		
Rock	8	0		
Grey roach	16	6		
Grey rock	24	0		
Rock	12	0		
Roach	6	6		
Rock	2	6		
Grey roach	9	0		
Black shale	1	6		
Grey shale	9	0		
COBBLE COAL	2	6	307	0
Clunch	18	6		
Dark shale	15	0		
Black shale	17	0		
COAL	0	2		
Clunch	1	6		
Rock	6	0		
Grey roach	4	6		
Strong roach	7	6		
Strong roach	10	6		
Grey shale	4	6		
Grey shale	9	0		
Rock	9	0		
Roach	13	6		
Rock	7	6		
Rock, hard	3	0		
Grey shale	4	6		
COAL	0	6		
Clunch	4	6		
Rock binds	10	6		
Grey roach	3	0		

Character of Strata.	Thickness		Depth.		
	Ft.	In.	Yd.	Ft.	In.
RIDER COAL	2	3	459	8	0
Clunch	6	9			
Rock	26	0			
Grey roach	37	0			
Rock, hard	4	0			
Rock, soft	5	0			
Grey roach	16	6			
Grey roach	4	6			
Grey shale	12	0			
Black shale	9	0			
WOODHEAD COAL	3	0		582	8
Stone	0	9			
Pricking	0	2			
OUSTER COAL	0	3			
Boring below the last Bed.					
Bind	9	0		583	10
Black shale	26	0			
Strong bands and shale	5	0			
Black shale	9	0			
Grey rock and soft roche	173	0			
Slate rock	49	0			
Grey shale	40	0			
Black shale	22	0			
Dark clunch	8	0			
Grey rock	6	0			
Black shale	13	0			
COAL	0	4			
Grey rock	6	0			
Black shale with bands	45	0			
Soft grey rock and shale	28	0			
COAL	0	3			
Black shale	0	3			
Clunch	1	0			
Black soft shale	1	0			
Grey shale	4	0			
Black shale	38	0			
Grey rock full of spar	2	9			
Black shale	10	9			
STINKING COAL	2	0			
Dark clunch	3	0			
Grey and white rock	19	8			
Light red shale	4	5			
Grey and white rock	3	3			
Conglomerate	1	3			
Red shale	4	0			
Black shale	12	0			
Smooth grey rock	9	0			
Red shale	3	8			
Grit bored into (said to be the First Grit)	8	4			
				1151	9

APPENDIX No. IV.

Geological Bibliography of the North Staffordshire Coalfields. By W. Gibson.

This list is founded on a Bibliography by Mr. J. Ward, published in the Transactions of the North Staffordshire Field Club, vol. xxiv, 1895, with additions in vol. xxviii, 1899, and vol. xxxix, 1902.

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(The numbers refer to the date of publication.)

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MAPS AND SECTIONS OF THE GEOLOGICAL SURVEY.

MAPS—SCALE 1 INCH TO A MILE.

QUARTER-SHEET 72, S.W. [Stafford, Stone, Uttoxeter, etc.] By E. Hull, 1852. Revised to 1855.

QUARTER-SHEET 72, N.W. [Hanley, Stoke-on-Trent, Cheadle, Newcastle-under-Lyme, &c.] By W. W. Smyth, and E. Hull, 1857. Revisions by A. H. Green, 1864.

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SHEET 18. Section from the Red Marl plain of Cheshire, across the Lower Carboniferous rocks of North Staffordshire. By J. Phillips and A. H. Green, 1866.

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SHEET 86. Sections of Shafts, &c. in the Pottery Coalfield, North Staffordshire. No. 1, Florence Colliery (No. 1 Pit). No. 2, Adderley Green Colliery (No. 8 Pit). No. 3, Glebe Colliery, Fenton. No. 4, Mossfield Colliery, Longton. No. 5, Sneyd Colliery, Burslem. No. 6, Ford Green New Pit. No. 7, Institute Sinking Pit, Whitfield. No. 8, New Engine Pit, Biddulph Colliery. No. 9, Talk o' th' Hill Colliery. No. 10, Jamage Colliery, Rookery Pits, New Shaft. No. 11, Silverdale District. No. 12, Grange Colliery Bassey Mine Pit. 1901.

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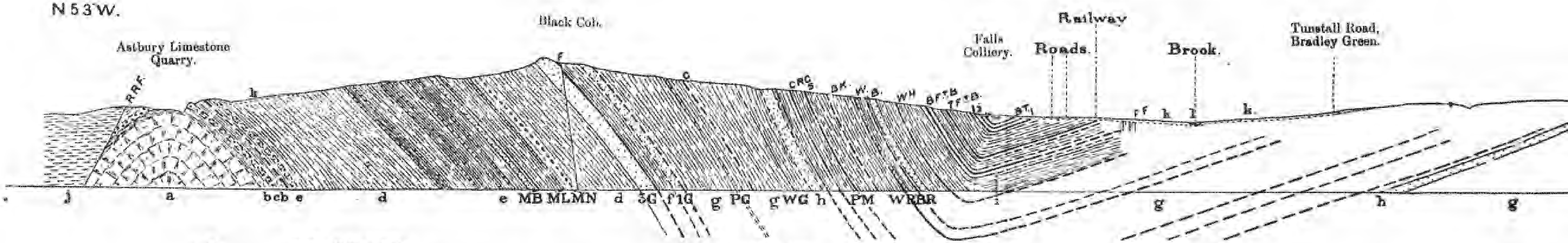
Fig. 1.—Section across the Biddulph Trough, by C. B. Wedd.

Scale, Horizontal and Vertical, 6 inches = 1 mile.



l.—Alluvium.
k.—Drift.
SUPERFICIAL.

j.—Trias under thin Drift. TRIAS.

B.T.—Bright Coal.
I.—Ironstone Mine Coal.
7 FT. B.—Seven Feet Bambury or Froggery Coal.
8 FT. B.—Eight Feet Bambury or Newpool Coal.
i.—Beds of *Carbonicola*.

W.H.—Whitehurst Coal.
B.R.—Bullhurst Rock.
B.—Bullhurst Coal.
W.R.—Winpenny Rock.
W.—Winpenny Coal.
B.K.—Brick-Kiln Row Coal.
P.M.—Pottery Marl.
S.—Silver Mine Coal.

C.R.C.—Cannel Row Coal.
h.—Beds of Sandstone.
W.G.—Whetstone.
C.—Crabtree Coal.
P.G.—Pebbly Grit.
g.—Shales, marls, fireclays and thin sandstones.
COAL-MEASURES.

F.—Fault. R.R.F.—Red Rock Fault. F.F.—Faulty Ground. Parts left blank where outcrops are uncertain. Thick lines are coal seams.

Fig. 2.—Generalized Section across the Pottery Coalfield, by W. Gibson.

Horizontal Scale, one inch = 1 mile.
Vertical Scale, one inch = ½ mile.

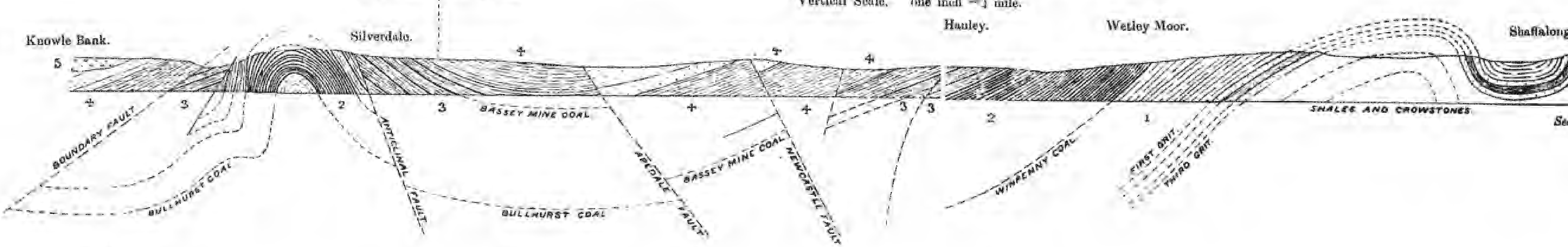


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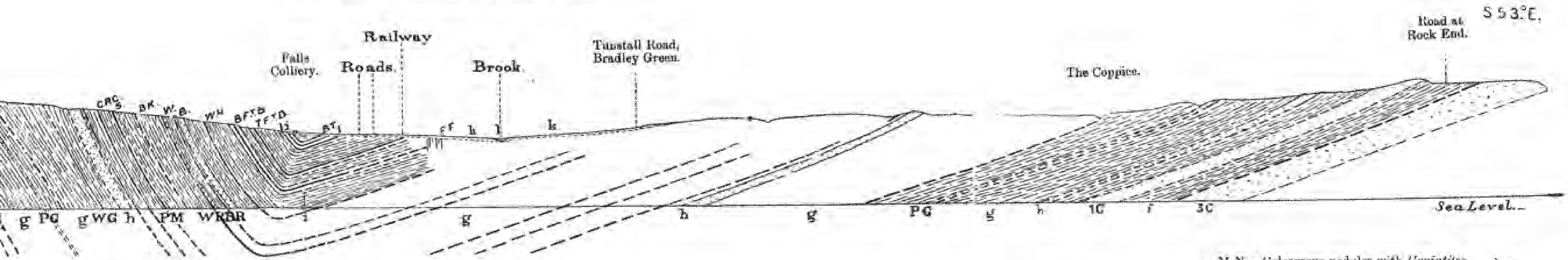
Fig. 1.—Section across the Biddulph Trough, by C. B. Wedd.

Scale, Horizontal and Vertical, 6 inches = 1 mile.



H.—Whitehurst Coal.
.—Bullhurst Rock.
Bullhurst Coal.
R.—Winpenny Rock.
—Winpenny Coal.
.—Brick-Kiln Row Coal.
.—Pottery Marl.
Silver Mine Coal.

F.F.—Faulty Ground.

C.R.C.—Cannel Row Coal.
h.—Beds of Sandstone.
W.G.—Whetstone.
C.—Crabtree Coal.
P.G.—Pebbly Grit.
g.—Shales, marls, fireclays and thin sandstones.

COAL-MEASURES.

1.G.—First Millstone Grit.
f.—Shale.
3.G.—Third Millstone Grit.

MILLSTONE GRIT.

M.N.—Calcareous nodules with *Goniatites.*
M.L.—Muddy limestone with *Goniatites.*
M.B.—Marine bed with *Glyphioceras*, etc.
e.—Shales with Crowstones.
d.—Shales.
c.—Tuff.
b.—Shales with limestone.
a.—Carboniferous Limestone.

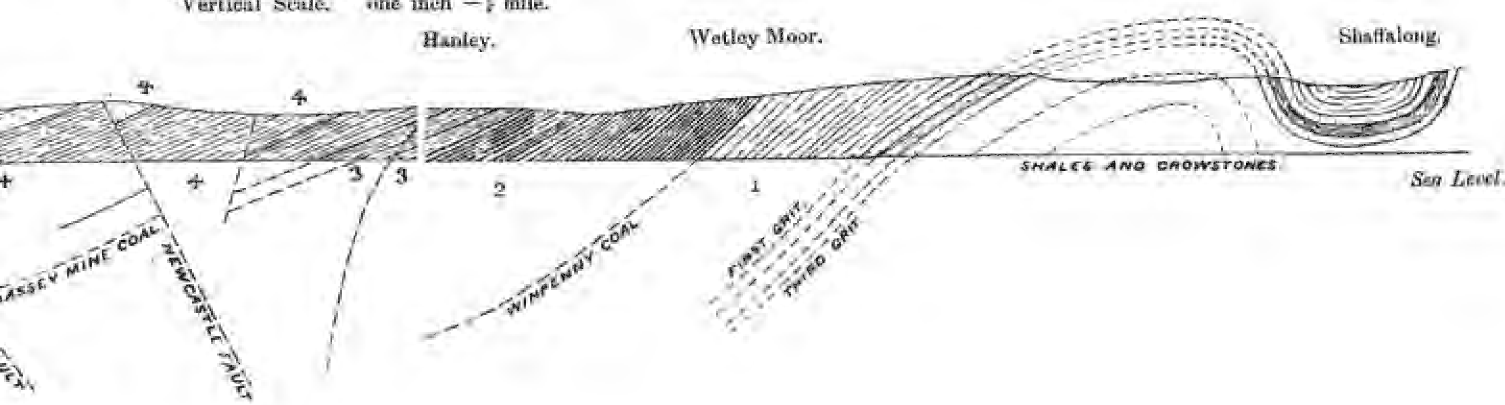
PENDLESIDE SERIES.

Parts left blank where outcrops are uncertain.

Thick lines are coal seams.

—Generalized Section across the Pottery Coalfield, by W. Gibson.

Horizontal Scale, one inch = 1 mile.
Vertical Scale. one inch = ½ mile.



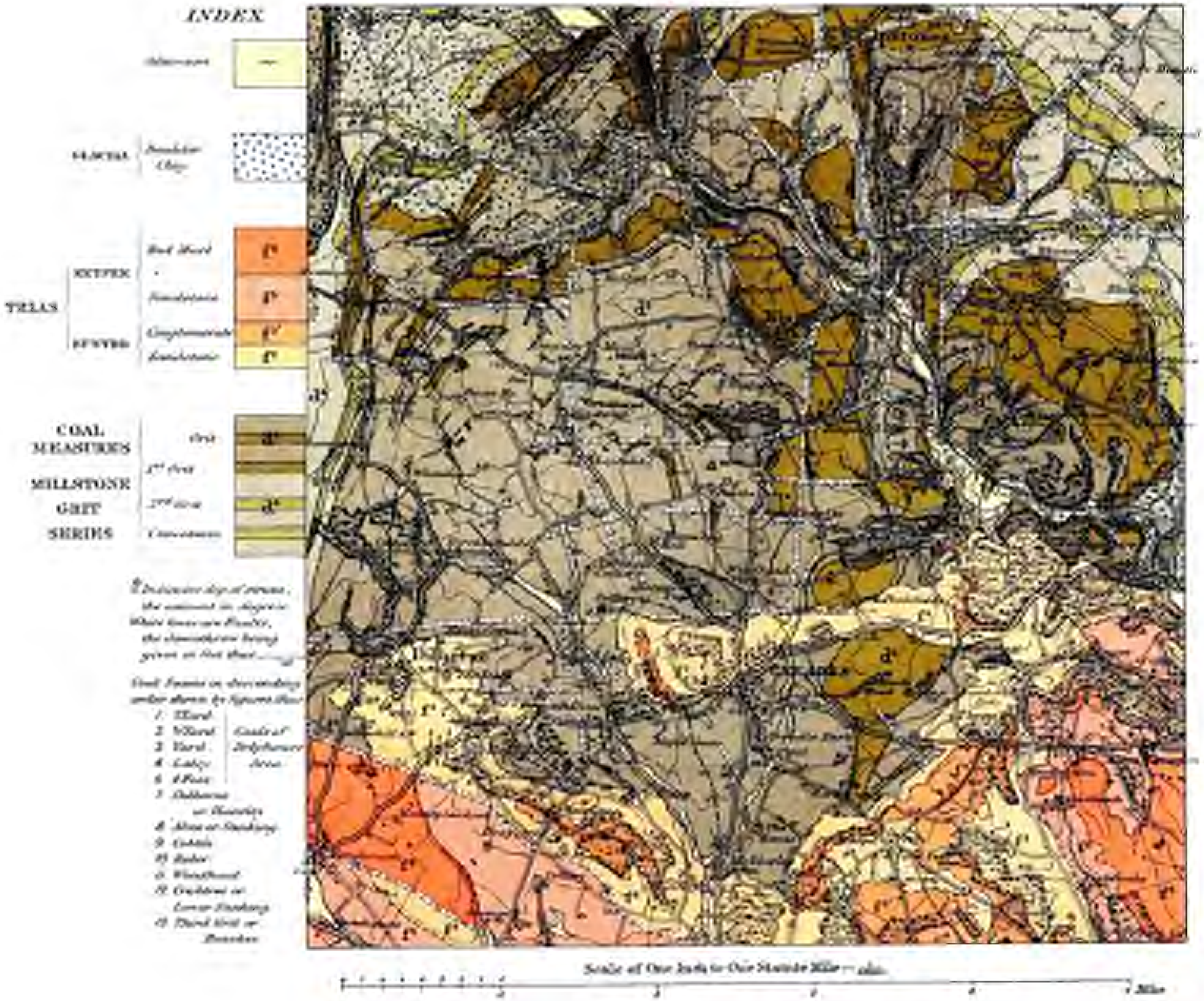
Explanation of Fig. 2.
1-3.—Grey or Chief Coal-bearing Series.
4.—Red and Grey Series.
5.—Bunter Conglomerate.

GEOLOGICAL SURVEY OF ENGLAND.

GEOLOGICAL MAP OF THE CHEADLE COALFIELD.

By George Barrow F.G.S.

Plate II.



The fossils illustrated in Plates III. IV. were kindly selected, as representing some of the commonest fossils of the Pottery Coalfield, by Dr. Wheelton Hind. They are reproductions by photography from Dr. Hind's Monograph on the British Carboniferous Lamellibranchiata. *Pal. Soc.*, Vols. XLVIII., XLIX., 1894, 1895.

PLATE III.

Fossil Shells from the Coal-Measures.

Fig. 1. Anthracomya modiolaris, *Sow.* Roof of the Holly Lane Coal. Adderley Green. *Pal. Soc.*, vol. xlix., pl. xiv., fig. 7.

" 2. Anthracomya modiolaris, *Sow.* Same horizon. Hanley and Bucknall Colliery. *Pal. Soc.*, vol. xlix., pl. xiv., fig. 2.

" 3-4. Naiadites modiolaris, *Sow.* Roof of the Hard Mine Coal. Adderley Green. *Pal. Soc.*, vol. xlix., pl. xvii., figs. 16–17.

" 5. Carbonicola turgida, *Brown. Pal. Soc.*, vol. xlviii., fig. 19.

" 6. Naiadites carinata, *Sow.* Roof of the Hard Mine Coal. Adderley Green. *Pal. Soc.*, vol. xlix., pl. xviii., fig. 12.

" 7. Anthracomya Adamsi, *var.* expansa, *Hind.* From the Little Mine Ironstone. Great Fenton. *Pal. Soc.*, vol. xlix., pl. xiii., fig. 2.

" 8. Naiadites quadrata, *Sow.* Above the Woodhead Coal. Froghall. *Pal. Soc.*, vol. xlix., pl. xviii., fig. 20.

" 9. Naiadites quadrata, *Sow.* Roof of the Hard Mine Coal. Adderley Green. *Pal. Soc.*, vol. xlix., pl. xviii., fig. 25.

" 10-11. Anthracomya dolabrata, *Sow.* From the Little Mine Ironstone. Great Fenton. *Pal. Soc.*, vol. xlix., pl. xiii., fig. 5–8.

" 12. Naiadites triangularis, *Sow.* From the roof of the Hard Mine Coal. Adderley Green. *Pal. Soc.*, vol. xlix., pl. xvii., fig. 34.

" 13. Naiadites carinata, *Sow. Pal. Soc.*, vol. xlix., pl. xviii., fig. 1.

" 14. Naiadites elongata, *Hind.* From the Knowles Ironstone. Fenton Park. *Pal. Soc.*, vol. xlix., pl. xviii., fig. 31.

" 15. Anthracomya Wardi, *Eth.* From the shale above the Bowling Alley Coal. Whitfield Collieries. *Pal. Soc.*, vol. xlix., pl. xv., fig. 20.

" 16. Anthracomya Wardi, *Eth.* From the shale above the Bowling Alley Coal. Adderley Green. *Pal. Soc.*, vol. xlix., pl. xv., fig. 14.

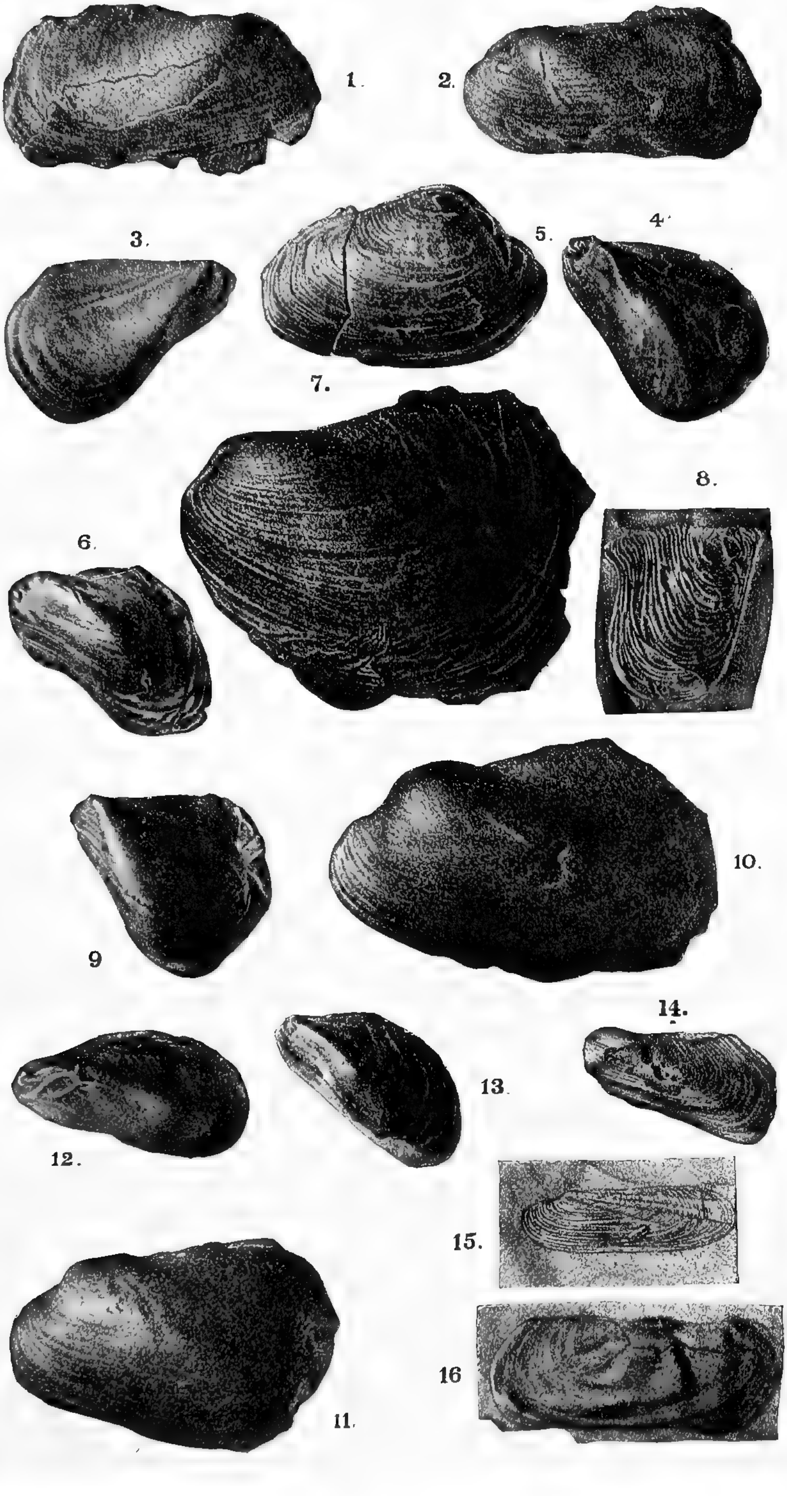

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PLATE IV.

Fossil Shells from the Coal-Measures.

Fig. 1-3. Carbonicola acuta, *Sow.* From the roof of the Cockshead Coal. Adderley Green. *Pal. Soc.*, vol. xviii., pl. iii., figs. 12, 8, 11a.

„ 4. Carbonicola aquilina, *Sow.* Black shale about the horizon of the Bambury Seams. Clough Hall Collieries. *Pal. Soc.*, vol. xlviii., pl. ix., fig. 26.

„ 5. Anthracomya senex, *Salter.* From the Cockshead Ironstone. Adderley Green. *Pal. Soc.*, vol. xlix., pl. xv., fig. 26.

„ 6. Carbonicola robusta, *Martin.* From the shale above the Stinking Coal. Froghall. *Pal. Soc.*, vol. xlviii., pl. ii., fig. 10.

„ 7. Carbonicola obtusa, *Hind.* Whitfield Collieries. *Pal. Soc.*, vol. xlviii., pl. vii., fig. 16.

„ 8. Anthracomya pulchra, *Hind.* From the lower part of the Burnwood Ironstone. *Pal. Soc.*, vol. xlix., pl. xv., fig. 29.

„ 9. Carbonicola cuneiformis, *Hind.* From the roof of the Hard Mine Coal. Bucknall. *Pal. Soc.*, vol. xlviii., pl. xi., fig. 24.

„ 10. Anthracomya Phillipsi, *Will.* From the Bassey Mine Ironstone. Chatterley. *Pal. Soc.*, vol. xlix., pl. xvi., fig. 11.

„ 11-12. Anthracomya Williamsoni, *Brown.* From the roof of the Hard Mine Coal. Adderley Green. *Pal. Soc.*, vol. xlix., pl. xiv., figs. 12 & 17.

„ 13-14. Carbonicola gibbosa, *Hind* From the roof of the Moss Coal. Fenton. *Pal. Soc.*, vol. xlviii., pl. viii., figs. 1a & 1b.

„ 15. Carbonicola cuneiformis, *Hind.* From a thin bed above the Cockshead Rock. Hulme Colliery. *Pal. Soc.*, vol. xlviii., pl. xi., fig. 25.

„ 16. and 16a. Anthracomya minima, *Ludwig.* From the Knowles Ironstone. Rail-cutting north of Golden Hill. *Pal. Soc.*, vol. xlix., pl. xvi., fig. 25.

„ 17. Anthracomya pulchra, *Hind.* From the lower part of the Burnwood Ironstone. Newchapel. *Pal. Soc.*, vol. xlix., pl. xv., fig. 30.

„ 18. Anthracomya Adamsi, *Salter.* From the Little Mine Ironstone. Great Fenton. *Pal. Soc.*, vol. xlix., pl. xii., fig. 9.

„ 19. Carbonicola nucularis, *Hind.* From the roof of the Hard Mine Coal. *Pal. Soc.*, vol. xlviii., pl. vii., fig. 25.

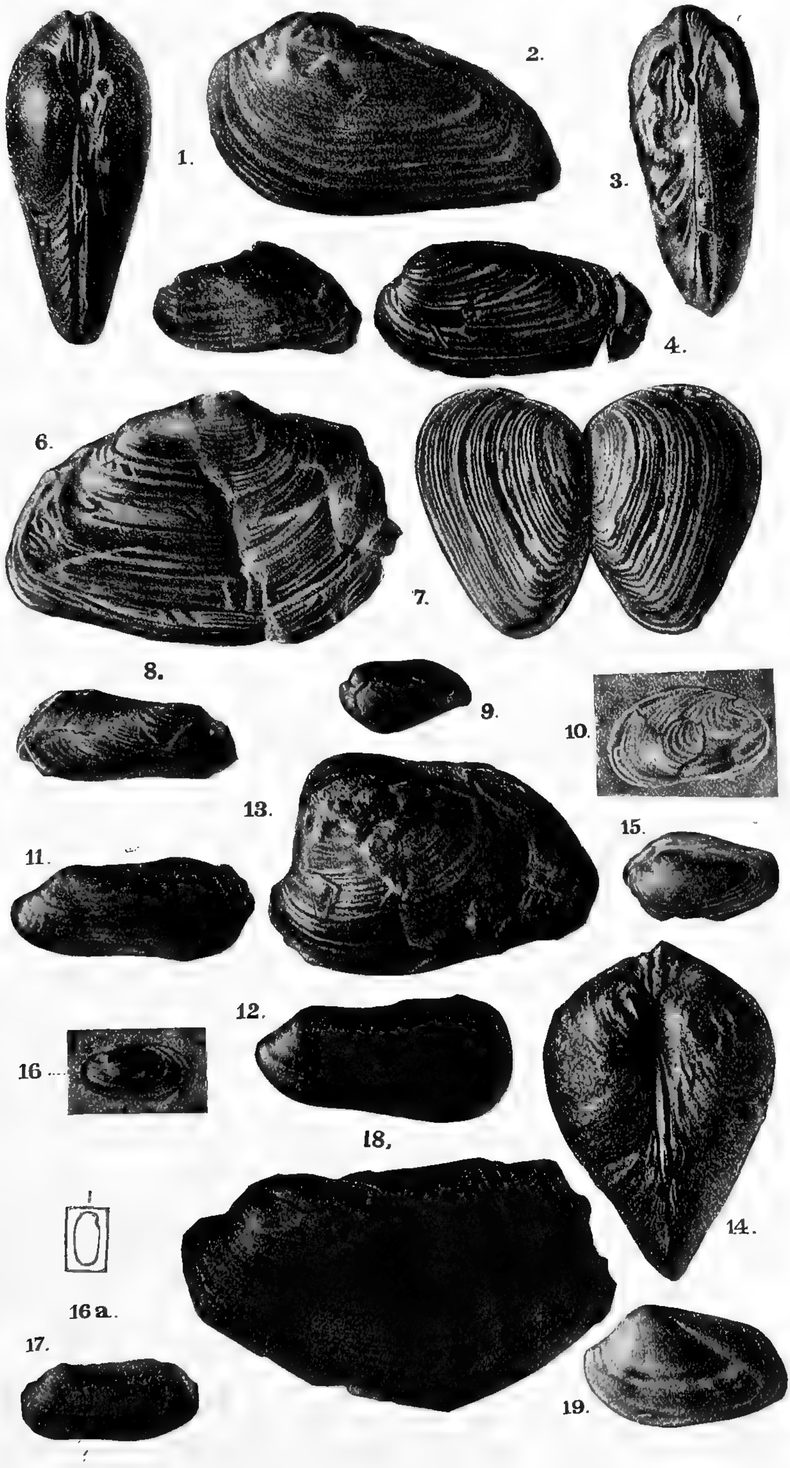
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PLATE V.

FOSSIL FISHES (TYPES) FROM THE COAL-MEASURES.

Fig. 1-7. Reproduced by permission from the *Quart. Journ. Geol. Soc.*, vol. xxii., pl. xx., 1866. After Young.

" 1. Cheirodus (Amphicentrum) granulosus, *Young*, one half the natural size.

" 2. Palative armature of C. granulosus, magnified.

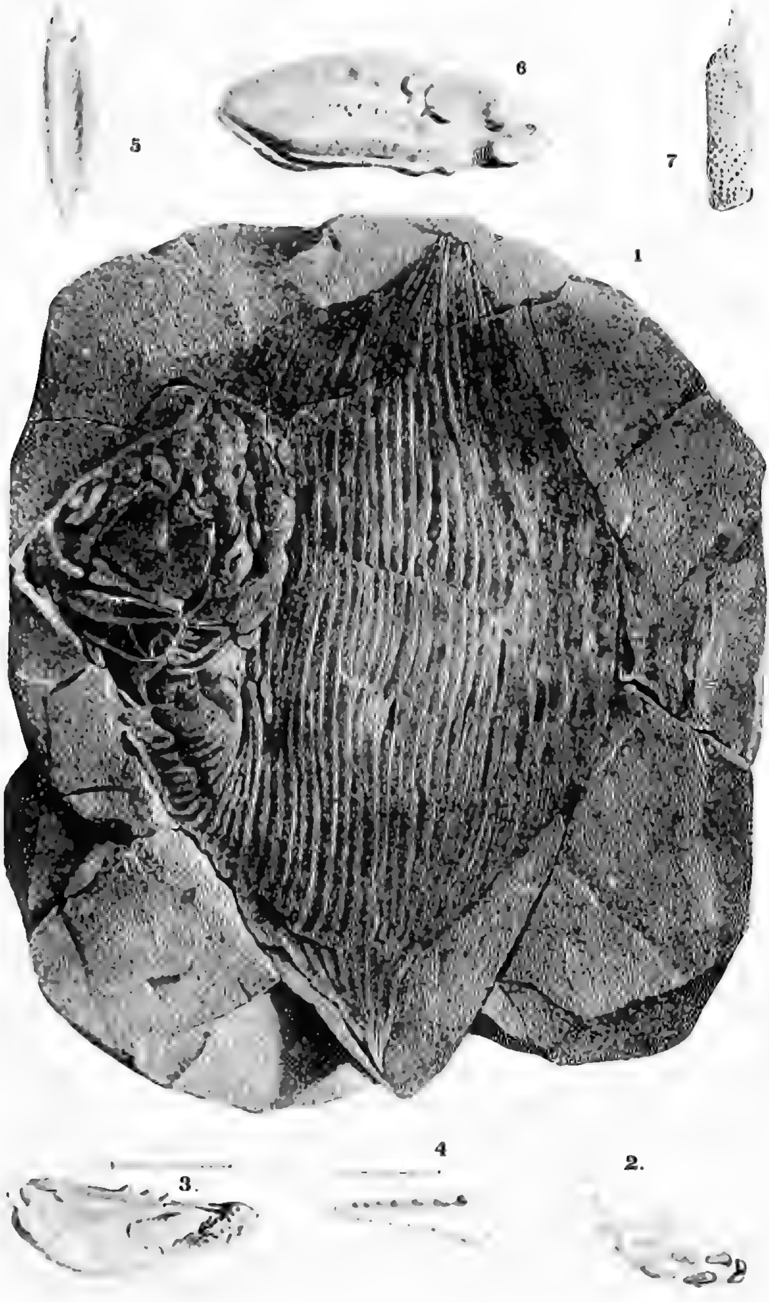
" 3. Mandible of C. granulosus, seen from without.

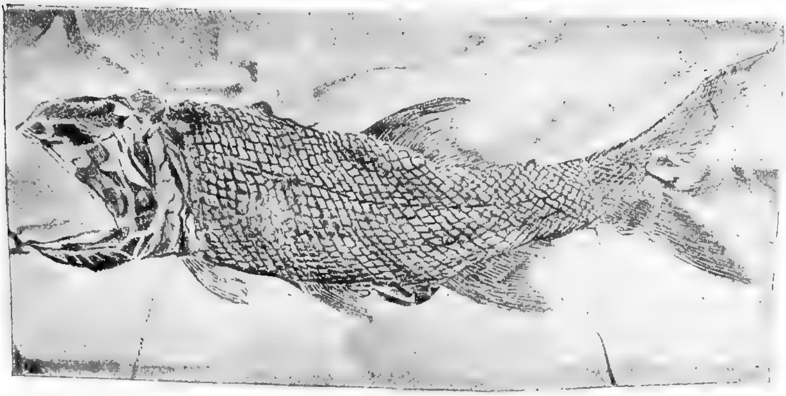
" 4. The same seen from above.

" 5. Inner surface of a scale of C. granulosus, natural size.

" 6. Maxilla of C. granulosus, natural size

" 7. Outer surface of a scale of C. grannlosus, natural size.

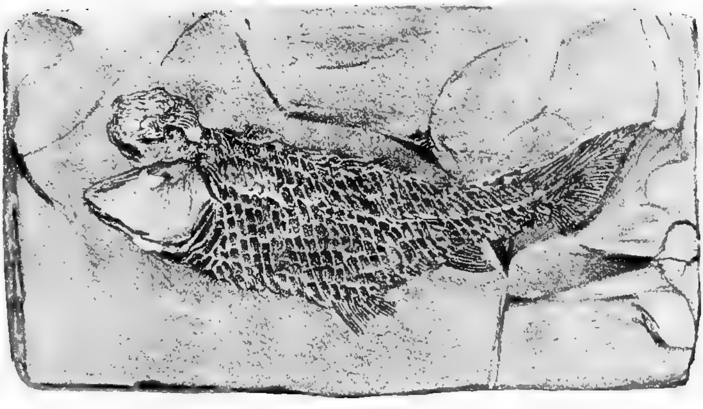

6
5
7
1
4
2.
3.



1

3a.

2



3.

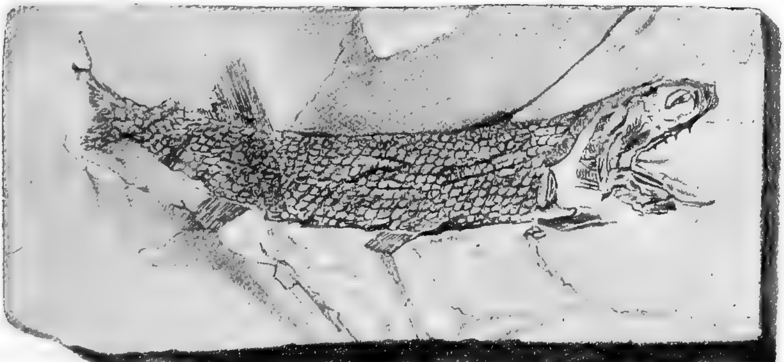


PLATE VII.

Fossil Fishes (Types) from the Coal-Measures.

Figs. 1. and 1a. to c. reproduced by permission from the *Quart. Journ. Geol. Soc.*, vol. xxii., pl. xxi. Figs. 2, 2a, by permission from the *Trans. North Staffordshire Institute of Mining and Mechanical Engineers*, vol. x. 1890.

Fig. 1. Mesolepis Wardi, *Young*. Natural size.

" 1a. Teeth of M. Wardi, twice the natural size.

" 1b. Outer surface of scales of M. Wardi, magnified.

" 1c. Inner surface of scales of M. Wardi, magnified.

" 2. Mesolepis scalaris, *Young*. After Traquair.

" 2a. External surface of a scale from the flank of M. scalaris; magnified two diameters.


2a
1c.
1b
2.
1.
1a.

PLATE VIII.

FOSSIL FISHES (EXCEPTING FIG. 4, ARE TYPES) FROM THE COAL-MEASURES.

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Fig. 1. Acanthodes Wardi, *Egerton*. Natural size.

„ 2. Diplodus equilateralis, Ward. Anterior aspect of tooth; natural size. After Ward.

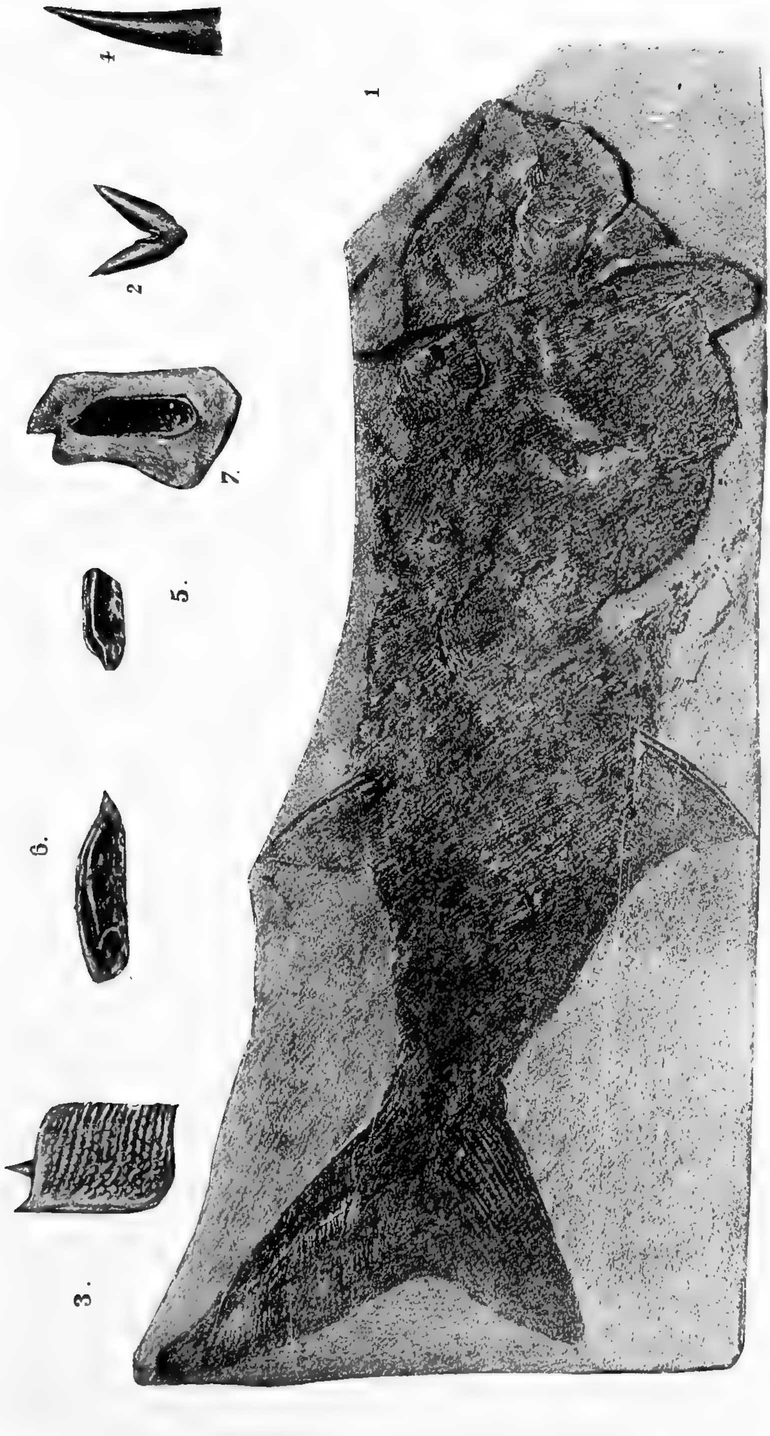
„ 3. Rhadinichthys Wardi, *Traquair*. View of the ornament of a scale from the flank. Magnified six diameters. After Traquair.

„ 4. Megalichthys Hibberti, *Agassiz*. Anterior aspect of tooth. Natural size.

„ 5. Megalichthys pygmæus, *Traquair*. Mandible broken off anteriorly. After Traquair.

„ 6. Mandible of M. pygmæus, seen from the external aspect. Natural size.

„ 7. Jugular plate of M. pygmæus. Natural size.



INDEX.

Names of persons (authors, observers, and informants) are in small caps.

(Names of fossils given in lists are not indexed.)